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Authors Guidelines

Thank you for deciding to submit your article to the Ege Journal of Fisheries and Aquatic Sciences (EgeJFAS). The journal welcomes the submission of articles that are of interest and high scientific quality. Authors should check the "Author Guidelines" very carefully before submitting their manuscripts. The instructions given here will ensure that your article's evaluation process (referee, publication, etc.) can proceed smoothly. Make sure your article is prepared and submitted in accordance with journal rules.

Submitted manuscripts will be checked primarily for compliance with journal subjects and rules. Manuscripts not complying with required formatting will be returned for correction. Papers outside the scope of the journal will be rejected.

GENERAL INFORMATION

Aim & Scope

Ege Journal of Fisheries and Aquatic Sciences (EgeJFAS) is open access, international, double-blind peer-reviewed journal publishing original research articles, short communications, technical notes, reports, and reviews in all aspects of fisheries and aquatic sciences.

The journal does not charge any submission and publication fees.

All articles receive DOI, are citable, published in PDF format.

The journal focuses on interdisciplinary studies that present new and useful information to the international scientific community/readership, and contribute to scientific progress. Before submitting your article, make sure it is suitable for the journal scopes.

The main functional areas accepted into the journal are listed as follows:

Marine and freshwater fisheries, Aquaculture, Vertebrate and invertebrate aquaculture (marine/freshwater), Planktonology and plankton culture, Living resources, Management and economics, Aquaponic, Seafood processing technology, Feeding and feed technologies, Fishing technology, Fisheries management, Population dynamics, Disease and treatment, Aquatic microbiology, Biology, physiology, Macroalgae, Biotechnology, Conservation and sustainability, Environments and ecology, Biogeography, Biodiversity, Climate effects, Pollution studies.

Ege Journal of Fisheries and Aquatic Sciences (EgeJFAS) (Su Ürünleri Dergisi) published quarterly (March, June, September, December) by Ege University Faculty of Fisheries since 1984.

The journal is published only as an e-journal since the 1st issue of 2020.

Language

Although articles in English and Turkish are accepted, priority is given to articles prepared in English in order to increase international readability and citation. Limited Turkish articles are published in each issue.

Manuscripts should comply with the standard rules of grammar and style of the language (English or Turkish) with appropriate spelling and punctuation in which they are written.

Editorial Policy and Referee Process

Manuscripts should not be copied elsewhere or submitted to another journal for parallel evaluation. Only original manuscripts are considered. It is evaluated with the understanding that the content is approved by all co-authors. Submitted manuscripts are first checked in terms of journal scope, language, presentation, and style. Manuscripts that are not suitable for these aspects will be returned without review.

In order to evaluate the appropriate articles, at least 2 or 3 external and independent referees who are experts in their fields are appointed by a member of the editorial board/section editor. Each manuscript is reviewed through a double-blind peer-review process (identities of neither authors nor peer reviewers are disclosed). Manuscripts returned to authors with referee reports should be revised and sent back to the editor as soon as possible.

Editor-in-chief/editors take the final decision (Accept, Reject) of the manuscript in line with the reviewer's opinions. All responsibility for the scientific content and expressions in the published article belongs to the authors. In accordance with the publication policies of EgeJFAS, the plagiarism report for the relevant manuscript is requested to be uploaded to the submission system by the responsible author.

Article Types

The types of articles accepted include original research articles (priority), short communications, reviews, reports, and technical notes in all aspects, focusing on interdisciplinary studies in the field of fisheries and aquatic sciences.

Original research papers: These are the article type that the Journal gives the most importance and priority. Should contain data obtained from original studies such as experimental results, field data, and/or theoretical studies.

Short communication: It should include original results and headings, like research papers. Articles provide important new research results/methods or discoveries that do not possible to publish as a full research paper. These articles that are narrowly focused deserve to be published faster than other articles.

Review: Reviews may summarize current research areas of broad importance or provide the readers with an insightful introduction to new and groundbreaking areas of research. It should be examined and discussed in-depth and comprehensively written by the author(s) who have expertise in the subject area, not just the literature surveys. Only invited reviews (in English) are considered for publication. If you would like to submit an invited review, please contact the editor-in-chief (editor@egejfas.org) and upload a review cover letter containing the requested information. As of 2023, reviews in Turkish will not be accepted. Publication of those accepted in the previous year will be completed in 2023.

Reports

Case reports encourage the submission of reports containing feature novel findings or new management strategies. Well-written and illustrated reports are taken into account.

Brief reports are short, observational studies that report the initial results or completion of a study or protocol.

Technical notes: They are short articles that focus on a new technique, method or procedure. It should identify significant changes or unique applications for the method described.

MANUSCRIPT SUBMISSION

The manuscript, when submitted together with the Cover Letter (Submission declaration and verification) and Copyright Form signed by the corresponding author on behalf of all authors, warrants (confirms) that it is original and has not been published elsewhere, has been approved - tacitly or expressly - by all co-authors and the responsible authorities at the institute where the work was carried out. The publisher will not be held legally responsible in case of any claim for compensation.

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Authorship Contributions, Conflict of Interest Statement, Ethics Approval, Data Availability should be written in the article after Acknowledgements and Funding section.

While starting

For submission of your manuscript prepared in accordance with the guideline to EGEJFAS please click here and after logging into your account (if you don't have an account please register at https://dergipark.org.tr/en/ . Your default login ID is your email address. Use your existing account; do not create new accounts with new submissions) use the "Submit Article" button on the home page of the journal to start submission. Before submitting a manuscript, do not forget to check the Submission Checklist.

After log in, the article submission process is completed in 5 steps. Upload your article information, article file, and other necessary documents step by step correctly. There is no transition to the next step until a step is completed.

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To verify the authenticity of the submitted article, a similarity report should be obtained by using the services of plagiarism detection software (Crossref Similarity Check, iThenticate: Plagiarism Detection Software). This report should be uploaded as a separate file named "similarity report".

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Please see our information on Ethical Principles and Publication Policy. Before submission, do not forget to read the "Ethical Responsibilities of the Authors".

Please ensure that any manuscript you submit to this Journal conforms to the Committee on Publication Ethics (COPE) recommendations for ethics, Best Practice Guidelines and as well as to the rules of Egejfas.

PREPARATION OF MANUSCRIPTS

Papers must be clearly written in Turkish or English. Manuscripts should be typed double spaced on A4 size paper in 12-point Times New Roman font including the references, table headings and figure captions with standard margins (25 mm) all around. The author's name should appear centred under the title. Numbered (1) note should give the author's institutional address and an asterisked (*) note should indicate the corresponding author's e-mail address. Degrees and qualifications should not be included.

Line and page numbers should be given from the first page of the manuscript.

Please prepare your typescript text using a word-processing package (save in .doc or .docx).

The complete manuscript should be in a single file containing full text, references, figures and tables. Figures and tables should be inside the manuscript placed properly (not at the end of manuscript). The line number should be given to the whole manuscript.

- Research papers and reviews must not exceed 25 manuscript pages including tables and figures (except systematic checklists).
- Short communications, technical notes, and reports which are results of brief but significant work, must not exceed 10 manuscript pages including tables and figures.

Papers must be clearly written in Turkish or English. Manuscripts should be typed double spaced on A4 size paper in 12-point Times New Roman font including the references, table headings and figure captions with standard margins (25 mm) all around. The author's name should appear centered under the title. Numbered ([1]) note should give the author's institutional address and an asterisked (*) note should indicate the correspondence author's e-mail address. Degrees and qualifications should not be included.

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The complete manuscript should be in a single file containing full text, references, figures and tables. Figures and tables should be at the end of the manuscript file and the locations should be indicated in the text.

- Research papers and reviews must not exceed 25 manuscript pages including tables and figures (except checklists).
- Short communications, technical notes and reports which are results of brief but significant work, must not exceed 10 manuscript pages including tables and figures.

First Page

The title should be short concise and informative, and be a statement of the main result/conclusion presented in the manuscript. The title should not contain abbreviations. Do not forget to add English title for Turkish article. The title should be written in sentence order.

Author Names and Affiliation

The first name and surname of each author should be clearly listed together and separated by commas. Provide exact and correct author names (forenames-surnames) as these will be indexed in official archives. Occasionally, the distinction between surnames and forenames can be ambiguous, and this is to ensure that the authors' full surnames and forenames are tagged correctly, for accurate indexing online.

Present the authors' affiliation addresses should be indicated at the author's name with superscript numbers immediately after the author's name. The full postal address of each

affiliation at the time of research should be listed in order: Department, institution, city with postcode, and country name.

Please clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. Provide an active e-mail address of the corresponding author. It is editorial policy to list only one author for correspondence.

ORCID numbers of all authors should be listed on the article title page as of June 2017. Authors who do not have an ORCID number are required to register their number at www.orcid.org. The orcid number is mandatory. Articles that do not have an ORCID number or are incorrect will not be evaluated.

Please refer to the journal's "Ethical Responsibilities of Authors" policy in the Ethical Principles and Publication Policy section for details on eligibility for author listing.

Abstract

English and Turkish abstracts (contributors who are not native Turkish speakers may submit their manuscripts with an English abstract only) of a maximum of 300 words should be included in all submissions. The abstract should be comprehensible to readers before they have read the full paper, and reference citations must be avoided. In the abstract, the importance of the work should be clearly stated; what, why, how it was done should be answered and the contribution of the results to the scientific world should be expressed. It should not contain undefined abbreviations.

Abstract should clearly the importance of the work described in the paper and reflect what was done, why it was done and what important results were achieved. It should not contain any undefined abbreviations and not be written in the first person.

Keywords

Below the abstract, please provide 4-6 keywords related to the study that will help to increase the discoverability of your manuscript. It is especially important to include words that are fundamental to your manuscript but are not included in the manuscript title or abstract to increase discoverability by indexing services.

Following pages

Following pages should contain the rest of the paper and should be organized into an Introduction, Material and Methods, Results, Discussion, Conclusion(s), Acknowledgements and Funding, Authorship Contributions, Conflict of Interest Statement, Ethics Approval, Data Availability, References. These should be capitalized. Please note that submissions without required documents/statements will not be accepted.

Introduction

Provide clearly and an adequate background, avoiding a detailed literature survey or a summary of the results. State the specific objective or hypothesis of the study.

Material and Methods

Provide adequate detail to allow the work/experiment to be reproduced. Methods already published should be mentioned by references. Significant modifications of published methods and new methods should be described in detail.

If the study requires "Ethics Committee Permission Certificate", be sure to report after the "Acknowledgements" section that permission has been obtained from the relevant institution. A copy of the "Ethics Committee Permission Documents" should be uploaded to the system. A detailed explanation on this subject has been made in the "Ethics Approval" heading above.

Results

Results should be clear and concise. Results for different parameters should be described under subheadings or in separate paragraph. Present your results in a logical sequence in the text, tables, and figures.

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The discussion should not repeat the results, but should provide a detailed interpretation of the data. The discussion should highlight the importance of the work and the resulting new insights. Only in exceptional cases may the results and discussion be combined with the editor's consent. Avoid extensive citations and discussion of published literature.

Conclusions

This should briefly state the major findings of the study.

Acknowledgements and Funding

Acknowledgements including people, grants, funds, projects, etc. should be kept brief and placed after conclusion section. Names of contributing people should be written clearly and fully.

Examples:

"The authors are grateful to John Nare, for his friendly collaboration and hospitality during the lipid analysis."

"The authors would like to thank Ken More for language revision."

Please clearly and fully specify the relevant funding information (name) with the grant number or codes.

Financial support acknowledgwment should be written like the example given:

"This study was supported by the Turkish Scientific and Technological Research Institution (Grant number: .....)."

"This work was supported by Ege University Scientific Research Projects Coordination Unit. Project Number: …."

"Author Mary Lee has received research support from Company A."

If the research has no specific financial support, please include the following statement:

"This research has not received a specific grant, fund or other support from any funding agency in the public, commercial, or not-for-profit sectors."

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The roles of all authors should be listed. Authors may have contributed to more than one role. These contributions should be placed in the text with the heading of "Authorship Contributions", after the "Acknowledgements" section of the article. See below examples:

Example: All authors contributed to the idea and design of the study. Material preparation and investigation were performed by [full name], [full name] and [full name]. The writing/editing was carried out by [full name] and all authors have read and approved the article.

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Full name/s: Supervision

Full name/s: Software, Validation

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Full name/s: Writing- Reviewing and Editing

For review article; it should be stated whose idea, who did the literature survey and data analysis, who wrote the draft, and who revised the criticisms.

For articles produced from student's dissertations or thesis, it is generally recommended that the student is listed as the principal author (A Graduate Student's Guide-APA Science Student Council 2006).

Changes to Authorship

At the time of submission, the author (s) information, the corresponding author and the order of the authors must be correct. Changing the author order, adding/deleting are not allowed during the revision phases. However, in rare cases, it can be applied when detailed and acceptable reasons are presented. All authors must agree with any addition, removal or rearrangement and the reasons for changes should be explained in detail. After the article is accepted, no changes can be made to the authorships.

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Authors should declare if they have any financial or personal relationships with any institution/organization or person that may adversely affect their work. Conflict of interest statement should be attached to the article after the Acknowledgements section.

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In the event of a potential conflict of interest, the authors must state: "The following financial interests / personal relationships may be potential competitive interests."

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All animal and human experiments conducted in the manuscript research should comply with the ARRIVE guidelines, EU Directive 2010/63/EU, The Code of Ethics of the World Medical Association (Declaration of Helsinki), and National Ethics Committee for Animal Experiments (HADMEK, HADYEK). If there is a human study in the article, it must comply with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

If the submitted article involves the use of animal (vertebrate) and human subjects, authors should prove that they have carried out the manuscript studies in accordance with the relevant laws and regulations and they have received the approval of the authorized institutional committee (s) (including the ethics committee name and reference number, if possible). If a study was granted exemption or did not require ethics approval, this should also be detailed in the manuscript.

Copies of approval should be uploaded to the system under the subheading "Ethics Committee Approval". In addition, an explanation should be added to the article with the title of "Ethics Approval" after the Acknowledgements section.

Examples:

"Approval was granted by the Ethics Committee of University B (Date.../No....)."

"This is an observational study. The ABC Research Ethics Committee has confirmed that no ethical approval is required."

"This article does not contain any human or animal studies performed by any authors."

"The authors declare that all applicable guidelines for sampling, care, and experimental use of animals in this study have been followed."

"Sampling and handling procedures of the fish were in accordance with an …… protocol approved by University of ……..".

"No specific ethical approval was necessary for this study."

Retrospective Ethics Approval

If necessary, an application should be made to the ethics committee and approval should be obtained before starting a study. Generally, retrospective ethical approval cannot be obtained. It may not be possible to consider such articles for peer review. In such cases, it is at the Editor's discretion to decide whether to proceed with the peer review.

Data Availability

Articles are open access and free to use. Published articles are archived permanently. Proper citation is required when using an article published in a journal.

In order for the datasets reflecting the results of the article should be accessible to the readers; the journal encourages that datasets may be stored in public repositories (where available and appropriate) and addressed in the article, provided in the article, or in supplementary files whenever possible, or available from the corresponding author upon request. Regarding data availability, authors can follow one of the ways described. Enquiries about data availability should be directed to the authors. This information should be placed in the text with the heading "Data Availability" after the "Acknowledgements" section of the article. See examples below:

Examples:

Data availability: All of the data summarized in the study are available in the (name) Data Repository, (link address).

Data availability: The data sets generated during and/or analysed during the current study will be provided by the corresponding author upon the request of the editor or reviewers.

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Scientific Style

In writing of systematic /biological papers, international terminology such as "International Codes of Zoological Nomenclature (ICZN), and International Code of Nomenclature for Algae Fungi and Plants (ICNAFP)(Formerly known as the International Code of Botanical Nomenclature - CBN) International Code of Botanical Nomenclature (ICBN)" must be strictly followed. The first mention in the text of any taxon must be followed by its authority including the year. The names of genera and species should be given in italics. Clearly write the full genus name at the first occurrence in the text, and abbreviate it when it occurs again. When

referring to a species, do not use the genus name alone; Be careful when using 'sp' (singular) or 'spp.' (plural).

Equations and units

Please ensure that equations are editable. Leave a space on both sides of the <, ±, =, etc. equations used in the text. For units and symbols, the SI system should be used.

Abbreviations

Please define non-standard abbreviations at first use in the text with full form followed by the acronym in parentheses. Use only the acronym for subsequent explanations.

Footnotes

Footnotes should be numbered consecutively. Those in tables or figures should be indicated by superscript lower-case letters. Asterisks should be used for significance values and other statistical data. Footnotes should never include the bibliographic details of a reference.

References

Full references should be provided in accordance with the APA style. The usage of reference managers as Mendeley© or Endnote© or an online reference manager as Citefast with the output style of APA 7th edition is advised in organizing the reference list.

Please ensure that every reference cited in the text is also present in the reference list (and vice versa) and avoid excessive referencing.

In-Text Citation

In-text citation to the references should be formatted as surname(s) of the author(s) and the year of publication (also known as the author-date system).

If a specific part of a source (book, article, etc) is cited directly, a page number should also be included after the date. If the full source is used, the citation page number is not displayed.

For example: Kocataş, 1978, p. 3

Citation can be shown in two ways: Parenthetical Citation or Narrative Citation.

References to be made at the end of the sentence should be shown in parentheses. If the cited reference is the subject of a sentence, only the date should be given in parentheses. There should be no parentheses for the citations that the year of the citation is given in the beginning of the sentence.

Citation examples according to the number of authors are given below.

One author:

Consider the following examples:

-…….(Kocataş, 1978)

- Kocataş (1978) states…….

- In 1978, Kocataş's study of freshwater ecology showed that….

Two authors:

If there are two authors, the surnames of both authors should be indicated and separated from each other by "and", (Geldiay and Ergen, 1972).

Consider the following examples:

-…….(Geldiay and Ergen, 1972)

- Geldiay and Ergen (1972) states……

- Similar results were expressed by Geldiay and Ergen (1972), Kocataş (1978).

More than two authors:

For citations with more than two authors, only the first author's surname should be given, followed by "et al." –in Turkish article 'vd.'- and the date (Geldiay et al.,1971; Geldiay vd., 1971).

See below examples:

-Geldiay et al. (1971) state…….

-……(Geldiay et al., 1971).

There are few studies on this subject (Geldiay et al.,1971).

Two or more works by different author:

When its needed to cite two or more works together, in-text citations should be arranged alphabetically in the same order in which they appear in the reference list and used semicolons to sparate citations.

For example: Several studies have reported similar results (Geldiay and Ergen, 1972; Kocataş 1978; Thurry 1987).

Two or more works by the same author:

If there are two or more works by the same author, list the years of publication in order, earliest first. For example: (Kocataş, 1978, 1979, 1981) or Kocataş (1978, 1979, 1981)

Citation to authors with more than one work in the same year:

The works should be cited as a, b, c, etc. after the date. These letters must be listed alphabetically according to the surname of the first author in the bibliography list.

For Example:

-Geldiay and Ergen, 1972a

-Geldiay and Ergen, 1972a, b

No authors:

If the author is unknown, the first few words of the source should be used and dated.

For example: (A guide to citation, 2017).

In some cases, "Anonymous" is used for the author, accept this as the name of the author (Anonymous, 2001). Use the name Anonymous as the author in the reference list.

No publication date:

If the publication date is unknown, write "n.d." (no date) in the in-text citation.

Example: (Geldiay, n.d.).

Citation to secondary sources:

In scientific studies, citation should be made to the original primary sources. Cite secondary sources when the original work is out of print, not available, or only available in a language you do not understand. If you want to cite a work that you can't find yourself, through a citation from another source, using the phrase "…….as cited in".

For Example:

(Geldiay and Ergen 1972, as cited in Kocataş, 1978)

Personal communication and unpublished results:

Personal communications, such as phone calls, emails, and interviews, are not included in the reference list because readers can't access them. The in-text citation is also formatted slightly differently as follow:

Example:

- Demands have been increasing lately. (A. Kale, personal communication, May 10, 2021).

General use of websites and software:

It should be showed as below.

-The website of Egejfas (www.egejfas.org) includes author guidelines.

-Statistical software SPSS (version 25) was used to analyze the data.

In References

All citations should be listed in the reference list, with the exception of personal communications and unpublished results.

All references must be written in English. If an article is written in a language other than English, give the title in English and indicate the language in which the article is in parentheses at the end of the source. Example: (in Turkish)

If the article has only an English abstract, indicate it in parentheses (English abstract) or (only English abstract)

References should be listed alphabetically ordered by the author's surname, or first author's surname if there is more than one author.

Hanging indent paragraph style should be used.

The year of the reference should be in parentheses after the author name(s).

The correct arrangement of the reference list elements should be in order as "Author surname, first letter of the name(s). (publication date). Title of work. Publication data. DOI

Article title should be in sentence case and the journal title should be in title case. Journal titles in the Reference List must be italicized and spelled out fully; do not abbreviate titles (For example; Ege Journal of Fisheries and Aquatic Sciences, not Ege J Fish Aqua Sci). Article titles are not italicized. If the journal is paginated by issue the issue number should be in parentheses.

DOI (Digital Object Identifier) information (if available) should be placed at the end of the reference as in the example. After added DOI information, "dot" should not be put. The DOI information for the reference list can be retrieved from CrossRef © Simple Text Query Form (https://doi.crossref.org/simpleTextQuery) by just pasting the reference list into the query box. After copying and pasting all the references of your article in the query box on this page, the DOI information is listed as added to the relevant reference. It is strongly recommended to provide DOI information of the references.

- For a reference with up to 20 authors, ALL authors (up to 20) are spelled in the reference list. When the number of authors is more than 21, "....." is used between the 19th author and the last author (APA 7th edition).

For example:

Bolotov, I.N., Kondakov, A.V., Konopleva, E.S., Vikhrev, I. V., Aksenova, O. A, Aksenov, A. S., Bespalaya, Y. V., Borovskoy, A. V., Danilov, P. P., Dvoryankin, G. A. Gofarov, M. Y., Kabakov, M. B., Klishko, O. K., Kolosova, Y. S., Lyubas, A. A., Novoselov, A. P., Palatov, D. M., Savvinov, G. N., Solomonov, N. M., ……..& Vinarski, M. M., (2020). Integrative taxonomy, biogeography and conservation of freshwater mussels (Unionidae) in Russia.Scientific Reports, *10*, 3072. https://doi.org/10.1038/s41598-020-59867-7

- In the reference list starting with the same surname and names (initials), works with a single author are put in chronological order first; Then, two-author works are taken into account in alphabetical order of the second author. Multi-author works are listed only chronologically.

For example:

Kocataş, A. (1978)

Kocataş, A., & Ergen, Z. (1972).

Kocataş, A., & Geldiay, R. (1972)

Kocataş, A., Ergen, Z., & Geldiay, R. (1980)

The citation of journals, books, multi-author books and articles published online etc. should conform to the following examples:

Journal Articles

Öztürk, B. (2010). Scaphopod species (Mollusca) of the Turkish Levantine and Aegean seas. Turkish Journal of Zoology, *35*(2), 199-211. DOI:10.3906/zoo-0904-23

Özbek, M., & Ulutürk, E. (2017). First record of Spongilla lacustris (Porifera: Demospongiae) from the Eastern Black Sea (Uzungöl Lake, Trabzon) (in Turkish with English abstract). Ege Journal of Fisheries and Aquatic Sciences, *34*(3), 341-346. https://doi.org/10.12714/egejfas.2017.34.3.14

Books

Parsons, T.R., Matia, Y., & Lalli, C.M. (1984). A manual of chemical and biological methods for seawater analysis. New York, Pergamon Press.

Kleiner, F.S., Mamiya, C.J., & Tansey, R.G. (2001). Gardner's art through the ages (11th ed.). Fort Worth, USA: Harcourt College Publishers.

Chapter in books

Gollasch, S. (2007). Is ballast water a major dispersal mechanism for marine organisms? In W. Nentwig (Ed.), Biological Invasions (pp. 29-57). Berlin: Springer.

E-books and chapter in e-books

Mitchell, J.A., Thomson, M., & Coyne, R.P. (2017). A guide to citation. Retrieved from https://www.mendeley.com/reference-management/reference-manager

Troy, B.N. (2015). APA citation rules. In S.T, Williams (Ed.). A guide to citation rules (2nd ed., pp. 50-95). Retrieved from https://www.mendeley.com/reference-management/reference-manager

Proceedings

Soultos, N., Lossifidou, E., Lazou, T., & Sergedilis, D. (2010). Prevalence and antibiotic susceptibility of Listeria monocytogenes isolated from RTE seafoods in Thessaloniki (Northern Greece). In Ş. Çaklı, U. Çelik, C. Altınelataman (Eds.), West European Fish Technologists Association Annual Meeting 2010 (pp. 94-98). İzmir, Turkey: Proceedings Book.

Websites

Mitchell, J.A. (2017, May 21). How and when to reference. https://www.howandwhentoreference.com

If the resource was written by a group or organization, use the name of the group/organization as the author. Additionally, if the author and site name are the same, omit the site name from the citation.

American Society for the Prevention of Cruelty to Animals. (2019, November 21). Justice served: Case closed for over 40 dogfighting victims. https://www.aspca.org/news/justice-served-case-closed-over-40-dogfighting-victims

Thesis

Acarli, S. (2005). Larval production of oyster. Doctoral dissertation, Ege University, Turkey.

Tables and Figures

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

The effects of different starch levels on the physical quality of high-oil extruded fish feed

Farklı nişasta seviyelerinin yüksek yağlı extrude balık yemlerinin fiziksel kalitesi üzerine etkileri

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Abstract: In this study, the effects of different starch levels (5%, 8% and 11%) on the physical properties of extruded fish feeds with high oil content (22%) were investigated. For this purpose, 3 types of extruded trout feed with different starch levels (S5, S8 and S11) were produced. Physical (moisture, feed diameter, bulk density and pellet durability) and chemical (lipid, starch, water absorption index, water solubility index and water stability) analyses of these feeds were performed in 3 repetitions on the samples taken from the extruder outlet, lubrication outlet and sieve outlet. An increase in the amount of starch in the feed caused an increase in feed diameter and durability of the pellets, while a decrease in bulk density was observed. According to the results of the chemical analysis, it was seen that the increase in the starch ratio had no effect on the crude oil and water solubility index values, the best water absorption index value was in the S8 feed, and the water stability values decreased from S5 to S11.

Keywords: Trout feed, extrusion technology, chemical analyses, water absorption index, water solubility index, bulk density

INTRODUCTION

The extrusion cooking technique has been used for many years to produce various types of animal feed and human food. It has been the main method used in the production of aquaculture feeds for the last three decades. The extruder machine consists of a section called the sleeve, in which one or two endlessly rotating screws are arranged one after the other, with varying tooth spacing from the inlet to the outlet. The process is based on the principle of generating heat (120-130°C) and mechanically cutting by applying high pressure 1-2 times (20-30 bar) to the feed mixture in the form of flour passing through the die (Sorensen, 2012; Khater et al., 2014). This process is also known as friction. The most important result of these processes is the gelatinization of starch granules in the feed mixture. Additionally, the presence of starch and a limited amount of oil in the feed mixture ensures that the pellet is water-resistant and hard (Yan et al., 2019).

When raw starch comes into contact with water without being exposed to heat, it absorbs 20-30% of water. However, starch is insoluble in cold water due to hydrogen bonds between molecules (Hongyuan et al., 2022). When the feed mixture is extruded at a humidity of 27-33% and a temperature of 115-140°C, these starch granules, which have the ability to absorb water, form gels. Due to the breaking of hydrogen bonds during gelatinization, starch granules are broken down, making it easier for water molecules to bind to hydroxyl groups. This leads to an increase in starch solubility (Cai and Diosady, 1993; Moscicki et al., 2013; Balakrishna et al., 2020). In a study using corn starch in a single-screw extruder, it was found that the water solubility of starch increases after extrusion (Chinnaswamy et al., 1990; Yan et al., 2019). While the solubility of raw starch in water before extrusion is 2.0%, this value increases to 28.8% after extrusion. Moreover, the water solubility reaches 35.4% in twice-extruded starches. The pellet acts as a binder during the process. In this process, the expansion rate increases with increasing cylinder temperature. The increased expansion rate allows the absorption of excess oil, which must be added for vacuum coating to create a high-energy feed (Sorensen, 2012).

Feeds with good physical properties maximize feed consumption and feed conversion rate in fish. This is because the feed should remain unchanged in terms of both physical and nutritional content until the fish consume it. Additionally, the feed encounters numerous stress factors that can cause breakage and dust throughout all stages, from shaping to the point of being provided to the fish. As a result, the presence of dust and small particles makes it difficult for the fish to consume the feed, leading to an increase in the feed conversion rate. Moreover, it is not desirable for the feed to be excessively hard. This is because, in such cases, the feed is not adequately broken down as it passes through the fish's gastrointestinal tract, preventing the nutritional content from reaching a suitable consistency for enzymatic degradation (Sorensen, 2012).

The physical suitability of extruded feeds is associated with functional properties such as solid density, water absorption index (WAI), water solubility index (WSI), water stability (WS), starch gelatinization, particle size, and powder. WSI is utilized to measure starch degradation and is defined as the amount of dry matter detected in the liquid phase of the gel formed during extrusion. A low WSI indicates minimal starch degradation, implying a lower amount of dissolved matter in extruded products (Hernandez-Diaz et al., 2007; Narbutaite et al., 2008). The high moisture content during the extrusion process reduces protein denaturation and starch gelatinization. One indicator of starch gelatinization is the water absorption index. WAI is expressed as the amount of gel obtained from a unit weight of dry matter. The cutting process applied during extrusion physically breaks down starch granules and accelerates water penetration into the starch granules. Extrusion operating conditions such as screw speed, geometry, temperature, and product properties such as amylose/amylopectin ratio and moisture content influence mechanical degradation and the amount of gelatinized starch (Lai and Kokini, 1990; Kokini et al., 1992). Various applications such as cutting, mixing, grinding, shaping and thermal treatment applied during extrusion cooking create the effect of gelatinization of the feed, protein denaturation, hydration, expansion of the feed, and texture change. In addition, the residence time of the feed mixture in the extruder is also important for the final product quality (Nwabueze and Iwe, 2010).

The aim of this study is to evaluate the effects of different starch levels on the physical quality of high-fat extruded fish feed, depending on the feed processing stages (extrusion, lubrication and final product).

MATERIALS AND METHODS

Experimental feed production

In this study, extruded trout feed containing 22% crude oil was produced with three different starch levels (5%, 8%, and 11%). The trial feeds were designated as S5, S8, and S11, and their formulations were prepared using the "Brill Formulation™" program (Version: 1.34.006). The formulation and experimental feed composition are presented in Table 1. In the feeds prepared iso-caloric (4.2 kcal/gr) and iso-proteic (40%), fish meal was used as the animal protein source, and a mixture of soybean meal and wheat flour was used as the plant protein source. The ratios of animal and plant protein sources in the feed were 20/60, 30/50, 40/40 (FM/SM). The experimental feeds were produced at a private commercial company using an EX 920 brand extruder machine. The vacuum coating method was employed during the lubrication stage. A standard feed was produced for approximately 1 hour until the extruder conditions stabilized. Once the extruder reached constant torque, pressure, and temperature conditions, the production of the trial feeds commenced. Molds with a diameter of 4.5 mm were utilized in the production of these feeds. For each trial feed, a total of 1 ton of production was conducted three times. In each production batch (1st, 2nd, and 3rd tons), 1 kg samples were collected from the extruder outlet, lubrication outlet, and sieve outlet. Physical and chemical analyses were performed three times for each sample group.

Table 1. Ration of trial feeds

	S5 (%)	S8 (%)	S11 (%)
Ingredients			
Fish meal	20.6	29.43	38.27
Soybean meal pulp	56.0	42.06	28.12
Wheat meal	3.34	9.24	15.14
Fish oil	19.74	18.95	18.15
Vitamin-Mineral	0.32	0.32	0.32
Total	100	100	100
Nutritional composition			
Crude protein (%)	40	40	40
Crude lipid (%)	22	22	22
Crude cellulose (%)	1.7	1.43	1.16
Starch	5.07	8.15	11.20
Total energy (kcal/kg)	4127	4171	4215
Vitamin A (KIU/kg)	10000	10000	10000
Vitamin.D_3	2000	2000	2000
Vitamin E	200	200	200
Vitamin K_3	11	11	11
Vitamin C	180	180	180

Analysis of the feed

Feed analyzes are examined under two headings: physical and chemical analyses.

Physical analyses

In this study, moisture content, feed diameter, bulk density and pellet durability were investigated as physical analyses.

As physical analysis, moisture content, feed diameter, bulk density and pellet durability were examined in the feeds.

Moisture content

The samples were ground to less than 1mm in Ika Brand MF 10 Basic (IKA-Werke GmbH & Co. KG) model mill. The moisture of the products was measured with a Sartarious brand MA 150 Model (Sartorius AG, Goettingen, Germany) moisture analyzer. Approximately 3 g of sample was weighed on the weighing pan of the device and dried with infrared rays, and moisture was calculated gravimetrically from percent weight loss.

Feed diameter

Diameter measurements were made with a caliper (Tesa IP67, Hexagon Switzerland) with a precision of 0.02 mm in 60 feeds taken from the extruder, lubrication and sieve outlets of 1,2 and 3 tons of production of each feed type. All measurements were performed in 3 repetitions.

Bulk density

The feed samples taken for analysis were poured into a 1 liter custom-made weighing container. After the weighing pan was filled to the top, its top surface was smoothed with a ruler. Then, Sartarious Brand GE 2102 (Sartorius AG, Goettingen, Germany) model with 0.01 g precision was weighed in a

precision tailor). Analyzes were performed in triplicate (Figure 1).

Bulk density was calculated with the following formula;

Bulk Density (g/L) = Container Full Weight – Container Empty Weight / Container Volume

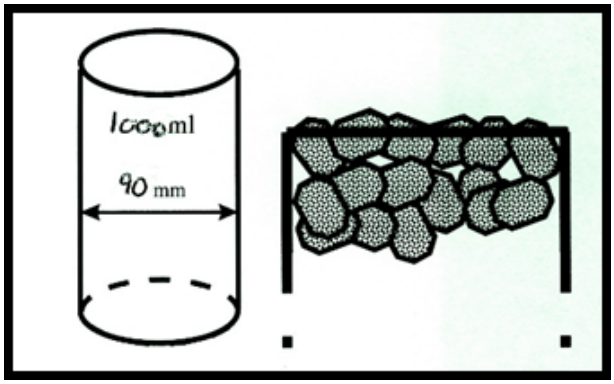

Figure 1. Bulk Density Determination

Pellet durability test

Pellet durability test was performed with DORIS (Durability on a Realistic Test) (Hendrix, Italy) testing device. Approximately 300 g of feed, cleaned of dust and broken pieces, was weighed on an analytical balance (M0) and poured from the inlet of the device. The device was run until all the bait samples had accumulated in the collection bottle. Then, the front cover was opened and the accumulated dust and broken pieces were added to the collection bottle. The collected product was passed through 1mm and 3.15 mm sieves. The amount of feed collected in the 1 mm sieve was weighed (Mb). The amount of dust collected at the bottom after passing through both sieves was also weighed (Ms). The durability value of the pellets was calculated according to the formula below. Analyses were performed in triplicate.

% Broken pieces= Mb/Mo x 100

% Dust = Ms/Mo x 100

DORIS value = % Broken piece + % Dust

Chemical analysis

As chemical analyses; lipid content, starch amount, water absorption index, water solubility (WSI) index and water stability (WS) of the feeds were determined.

Lipid content

Lipid analysis was performed by petroleum ether extraction process in FOSS brand Soxtec 2055 oil extraction device (FOSS Analytical, Denmark). The result of the analysis was calculated with the following formula;

Lipid% = (final sample weight - initial sample weight) / feed weight x 100

Analyzes were performed in triplicate.

Starch amount analysis

The amount of starch was investigated by measuring the optical rotation degree of the solute with HCl after removal of optically active solutes in the sample.

The degree of optical rotation of the samples was measured with MACHIMPEX Brand WXG-4 Model analog polarimeter (BANTE INSTRUMENTS CO., LTD.China). Analyzes were performed in triplicate. The result of the analysis was calculated with the following formula;

Starch = 2000 x P / $[\alpha]_D$

$[\alpha]_D$: Wheat Flour specific turning degree (degrees.mL/g.dm) = 182.7

$[\alpha]_D$: Specific degree of conversion of feed and soy (degrees.mL/g.dm) = 184

P: Polarimeter read value

Water absorption index (WAI)

The water absorption index is defined as the amount of gel obtained from a unit weight of dry matter. Analysis was done with modification of the method described by Anderson et al. (1969). The following formula was used to calculate WAI values.

WAI = Amount of Gel in Tube / Amount of Dry Matter of Sample x Amount of Sample

Results are given in g gel/g dry sample. Analyzes were performed in triplicate in all trials.

Water solubility index (WSI)

It is defined as the amount of dry matter detected in the liquid phase obtained in the water absorption index.

After determining the amount of liquid phase taken into tared drying containers, it was dried at 104 ^{0}C for 24 hours and the water solubility index per unit weight was calculated.

The following formula was used to calculate WSI values.

WSI = Amount of Dry Matter in Liquid Phase / (For example Amount of Dry Matter x Amount of Sample) x 100

Analyzes were performed in triplicate in all trials.

Water stability determination (WS)

A 10-g feed sample, whose dry matter amount was known in advance, was placed in a plastic container and filled with seawater to cover the feed by 1 cm. The tightly closed container was shaken in the incubator at 24°C and 1400 rpm for exactly 15 minutes. When shaking was completed, the container was weighed and dried in a tared conical flask in an oven set at 103°C for 24 hours. The samples coming out of the oven were brought to a constant weight in a desiccator and weighed.

Water stabilization was calculated according to the weight difference in dry matter with the following equation.

Loss in 10 g Feed (g) = [(Feed Amount(g) – Moisture (g)) – (Feed (Oven)]

All analyzes were performed in triplicate.

Statistical analysis

The data obtained as a result of physical and chemical tests were evaluated with the ANOVA parametric test using the Statistical Package for Social Science (SPSS for Windows; ver. 14.0, California, USA) program. At the same time, multi-factor ANOVA test was used to analyze the data, taking into account the levels of soybean meal and fish meal in the diet as the main factors. Some evaluations were made with the Independent Sample Test. Tukey test was used to find out which factors the difference depended on in cases where there was a difference between the factors as a result of the analysis of variance.

RESULTS

The results of the physical analysis can be viewed in Table 2.

Moisture

The moisture content of S5 feed at the extruder outlet was significantly higher than S8 and S11 feed ($p < 0.05$). This is due to the difficulties encountered during the pelletizing stage of S5 feed. Oil and water had to be added to the mixture to ensure that the feed adhered and held together. When the lubrication outputs of the feeds were analyzed, the moisture content of S5 feed was significantly higher than the other feed groups ($p<0.05$). Similarly, high moisture values were also observed in the sieve outlet of S5 feed. There was no statistical difference ($p>0.05$) between S8 and S11 feeds in terms of moisture content at all production stages (Table 2). When the results were analyzed according to raw materials, there was a statistically significant difference in the S5 (20/60) and S8 (30/50) feeds ($p<0.05$), while there was no difference in the S 11 ($p>0.05$) feed.

Feed diameter

Upon examining the samples taken at all stages of production (extruder, lubrication, and sieve exit), it was observed that the S5 feed had the smallest mean diameter, while the S11 feed had the largest diameter value (Table 2). However, when statistically analyzing the values, it was concluded that the difference between the S5 and S8 feeds was not significant ($p>0.05$). On the other hand, the diameter values of the S11 feed were found to be significantly different from the other two feeds ($p<0.05$).

When the results were analyzed according to raw materials, there was a statistically significant difference in the S5 (20/60), S8 (30/50) and the S 11 (40/40) feeds ($p<0.05$).

Bulk density

Based on the starch content of the S5, S8, and S11 feeds, a decrease in bulk density was observed at the extruder exit. There was no statistically significant difference in bulk density between the extruder outputs of the S5 and S8 feeds ($p>0.05$). However, the S11 feed group showed a significant difference compared to the other two feeds ($p<0.05$).

At the lubrication outlet, the S11 feed demonstrated a statistically significant difference ($p<0.05$) from the S5 and S8 feeds, similar to the extruder outlet. The density of the S11 feed was lower than that of the other two feeds. There was no statistical significance in the densities of the S5 and S8 feeds ($p>0.05$).

According to the sieve output data, an increase in starch content and a gradual decrease in bulk density were observed, which were considered statistically significant differences ($p<0.05$).

When the results were analyzed according to raw materials, there was a statistically significant difference in the S8 (30/50) and S 11(40/40) feeds ($p<0.05$), while there was no difference in the S5 (20/60) ($p>0.05$) feed.

Table 2. Physical analysis results

Physical analyses	Trial Feeds	Production Phase		
		Extruder outlet	Lubrication outlet	Sieve outlet
Moisture (%)±SD	S5	22.99a*±0.17	11.21a±0.10	13.26a±0.25
	S8	21.67b±0.19	6.65b±0.1	6.88b±0.14
	S11	21.65b±0.19	7.07b±0.05	6.98b±0.07
Feed Diameter(mm)±SD	S5	4.66b±0.02	4.78b±0.03	4.76b±0.03
	S8	4.76b±0.05	4.85b±0.04	4.85b±0.07
	S11	5.09a±0.08	5.19a±0.05	5.1a±0.04
Bulk Density (g/l)± SD	S5	498.13a±3.52	599.1a±5.43	608.71a±2.2
	S8	470.74a±5.05	589.05a±4.3	579.71a±3.13
	S11	422.60b±4.11	529.94b±2.56	538.98b±2.28
Pellet Durability (%)±SD	S5	NA	NA	NA
	S8	NA	9.73a±0.66	11.14a±0.29
	S11	NA	3.94b±0.60	3.04b±0.13

Values represent means ± SD
*Values in the same row with different letters were significantly different ($P<0.05$)
NA: Measurement could not be taken.

Pellet durability

Due to the low amount of starch in the S5 feed and as a result, the gelatinization process did not occur, the die was clogged and the product in proper pellet form could not be obtained. The pellet durability test, evaluated only in the S8 and S11 feeds, showed that the percentage of dust and broken pieces was higher in the S8 feed compared to the S11 feed ($p<0.05$) based on the results of the DORIS test conducted on the samples taken from the lubrication outlet. Similarly, in the samples taken from the sieve outlet, the highest amount of dust and broken pieces was obtained in the S8 feed, and a statistically significant difference was found when compared to the S11 feed ($p<0.05$)

When the results were analyzed according to raw materials, there was no difference statistically significant difference in the S8 (30/50) and S11 (40/40) feeds ($p>0.05$).

The results of chemical analyses are given in Table 3.

Lipid content;

Since fat is not added to the feed during the extruder stage, the values obtained are lower than the targeted values in the ration. The crude lipid analysis results in the samples taken from the extruder outlet did not show a statistically significant difference among the trial feeds group ($p>0.05$).

At the lubrication outlet, there was a decrease in the absorbed fat ratios due to the increase in the starch amount in the S5, S8, and S11 feed groups, and a statistically significant difference was observed ($p<0.05$).

When comparing the crude lipid analysis values of the sieve outlets of the S5, S8, and S11 feeds, there seemed to be a decrease in the absorbed fat ratio due to the increased starch amount. ($p<0.05$) (Table 3).

When the results were analyzed according to raw materials, there was a statistically significant difference in the S5 (20/60) and S8 (30/50) feeds ($p<0.05$), while there was no difference in the S 11 ($p>0.05$) feed.

The amount of starch;

The starch content in the samples collected from all production stages was found to be similar to the expected values based on the formulation. As a result, a statistically significant difference was observed between the measured starch content and the expected ratio values ($p<0.05$).

When the results were analyzed according to raw materials, there was a statistically significant difference in the S5 (20/60) feed ($p<0.05$), while there was no difference in the S8 (30/50) and S 11 ($p>0.05$) feeds.

WAI values;

Due to the high moisture content of the samples taken from the extruder outlets of the trial feeds, WAI, WSI and WS analysis could not be carried out in the samples.

The water absorption index was evaluated at the lubrication and sieve outlets of the trial feeds. In the samples taken from the lubrication outlet, it was determined that S5 had the lowest WAI value, while S8 had the highest WAI value. It was observed that the WAI values of the three feed types differed significantly at the $p<0.05$ level.

At the sieve outlet, the highest WAI value was obtained in S8, while the lowest WAI value was observed in the S5 feed among the three feed samples. There was no statistically significant difference between the groups ($p>0.05$).

In general, it can be concluded that for lubrication and sieve outlet, the WAI value was lower in S5 feed, while S8 and S11

Table 3. Chemical analysis results

Chemical analyses	Feed Types	Production Phase		
		Extruder outlet	Lubrication outlet	Sieve outlet
Lipid (%)	S5	3.73a±0.08	21.76a±0.27	21.41a±0.07
	S8	3.33a±0.06	20.36b±0.08	20.10a±0.22
	S11	3.81a±0.04	19.60c±0.16	19.85a±0.10
Starch (%)	S5	4.95a±0.41	4.96a±0.12	5.07a±0.17
	S8	8.81b±1.04	7.73b±0.24	7.95b±0.34
	S11	10.9c±0.84	10.93c±0.51	11.23c±0.49
WAI (g/g)	S5	NA	3.38a±0.06	3.55a±0.08
	S8	NA	4.12a±0.08	4.04a±0.04
	S11	NA	3.86a±0.03	3.8a±0.19
WSI (%)	S5	NA	1.98a±0.06	2.42a±1.04
	S8	NA	1.97a±0.14	2.15a±0.24
	S11	NA	2.01a±0.25	1.85a±0.07
WS (g/g)	S5	NA	1.22a±0.5	1.60a±0.34
	S8	NA	0.45b±0.19	0.16b±0.2
	S11	NA	0.27c±0.1	0.43c±0.05

Values represent means ± SD, and,
NA: Measurement could not be taken.

feeds were relatively similar and higher than S5. When the results were analyzed according to raw materials, there was a statistically significant difference in the S8 (30/50) and S 11 (40/40) feeds ($p<0.05$).

WSI values;

The water solubility index (WSI) was evaluated at the lubrication and sieve outlets. There was no statistically significant difference observed in the WSI values among the samples taken from the lubrication outlets ($p>0.05$). Similarly, no statistically significant difference was found in the WSI values at the sieve outlet for the three feed types ($p>0.05$).

When the results were analyzed according to raw materials, there was a statistically significant difference in the all trial feeds group ($p<0.05$).

WS values;

The water stability (WS) values of the feed samples taken from the lubrication outlet were evaluated, and statistically significant differences were observed ($p<0.05$). The WS values showed a decreasing trend from S5 to S11 feed samples. Similarly, significant differences were found in the WS values of all feed groups in the samples taken from the sieve outlet ($p<0.05$). The highest dry matter loss was observed in the S5 feed, while the least loss was observed in the S8 feed.

When the results were analyzed according to raw materials, there was a no statistically significant difference in the S5 (20/60) feed ($p>0.05$) while there was statistically significant difference in the S8 (30/50) and S 11 (40/40) feeds. ($p<0.05$).

DISCUSSION

Moisture

When comparing the moisture values, it is observed that the samples taken from the extruder outlet have higher moisture content compared to the samples taken from the lubrication and sieve outlet, even though the moisture content of all raw materials used in the formulation is consistent. This can be attributed to the addition of steam during the conditioning phase of the extrusion process, which increases the moisture content of the feed. This situation encountered during the extrusion phase shows a similar situation to the study that stated that in terms of feed technology, in wheat extrusion, the extruder machine did not work efficiently when extruding wheat with moisture addition below 20%, so the starting point was 20% (Adhikari and Adhikari, 2015). Additionally, the lower moisture values in the samples taken from the lubrication and sieve outlets can be attributed to the drying process that the products undergo after extrusion. However, since the dryer temperatures and residence time in the dryer were kept constant for all three feeds, the higher moisture values observed in the samples taken from the sieve and lubrication outlets of the S5 feed indicate an anomaly or deviation from the expected moisture level. Due to the high moisture content in the extruder stage, the incomplete gelatinization of the starch due to the low starch content of the S5 feed, and the fact that this feed contains a higher amount of soybean meal, the mold was clogged and pellets in proper form could not be obtained. It is also compatible with the results of other studies reporting that maximum gelatinization in extruded feeds occurs between 22-28% (Owusu-Ansah et al., 1983; Gomez and Aguilera, 1984; Case et al., 1992; Da Silva et al., 1996)

It is understood from the results obtained that the moisture content of the trial feeds varies depending on the feed production stages and starch sources. The high use of vegetable raw materials compared to fish meal has caused these results.

Feed diameter

When examining the feed diameter values, it was observed that the diameters increased with the increase in starch. The lowest diameter values were measured in the S5 feed, while the highest values were measured in the S11 feed. Due to the positive effect of wheat flour on gelatinization and expansion, in this production where the expansion control unit is also disabled, the diameter values of the S11 feed, which has the highest starch content, are higher than the others. In addition, the negative effect of soybean on expansion also supports this result and explains the fact that S5 feed with less starch and more soybean has the lowest diameter average and S11 feed with more starch and less soybean has the highest diameter average. Therefore, all results evaluated according to raw materials contain differences.

Bulk density

The expansion control unit (ECS) was not activated during production, as the effects of starch on expansion were also questioned in the experiments. When examining the Bulk Density values, it is observed that the volume of the feed changes with the expansion, which is positively influenced by the increase in starch. This, in turn, affects the density values. In our study, the inverse relationship between bulk density and the amount of starch is clearly evident, with statistical significance demonstrated at the $p<0.05$ level for the lubrication output. A decrease in bulk density was observed as the starch level increased. Although there is no difference in extruder outlet in terms of starch sources, it is seen that the difference increases as the usage rates of animal and vegetable origin raw materials approach each other.

Pellet durability

The low amount of starch contained in the S5 feed had a negative impact on pellet formation during the extrusion stage. The lubrication outlet of the third-ton production became clogged, resulting in distorted pellet shapes for the feed. This situation led to excessive waste in the feed, and an insufficient number of samples could be taken to determine pellet durability. In the case of the other group feeds, the durability of the pellets increased in parallel with the amount of starch. The use of raw materials of animal/vegetable origin in the ratios of 30/50 or 40/40, depending on the feed production stages, had

no effect on pellet durability. According to researchers (Cheftel et al., 1985; Kannadhason et al., 2011), it has protein binding properties and therefore, as the protein ratio in the feed mixture increases, PDI values also increase. However, in this study, since the protein ratios of all trial feeds were similar, no differences were observed according to starch sources.

Lipid

In the study, there was a significant increase in the amount of absorbed oil with the increase in the starch content in the lubrication outlets of S5, S8 and S11 feeds ($P<0.05$). Since the effects of starch on expansion were also investigated in this study, the expansion control unit (ECS) was not used during feed production. Therefore, the density values of the trial feeds are lower (floating feed) than the densities of commercial feeds (sinking feed). For these reasons, S11 feed has a more porous and irregular structure. In this case, the S11 feed absorbed more oil because it was more porous than normal, but it also vomited more oil due to the irregularity in its structure.

The lowest intensity value of S11 compared to the others also supports this interpretation, as the expelled oil created voids, causing the feed to lose weight without changing its volume.

While the lipid contents of the trial feeds had a significant difference in the extruder and lubrication stages according to the raw metarials, no statistically significant difference was observed in the sieve outlet.

Starch

When the physical and chemical analysis results of samples taken at different production stages and tons from S5, S8, S11 feeds produced under the same production conditions with rations with different starch levels are compared, it is seen that the results are different from each other. The low amount of starch contained in the S5 feed negatively affected the pellet formation during the extrusion stage. The die started to clog and the amount of wastage increased. While the lipid contents of the trial feeds had a significant difference in the extruder and lubrication stages according to the raw materials, no statistically significant difference was observed in the product outlet.

WAI values

The lower amount of starch used in the S5 feed compared to the other feeds resulted in lower Water Absorption Index (WAI) values due to reduced gelatinization. Furthermore, the contribution of soy in the S5 feed had a negative impact on the WAI value Similarly, despite the high amount of starch, the high content of fish meal in S11 feed negatively affected gelatinization. As a result, the S8 feed, where the ratio of soybean to fish meal is more balanced, exhibited higher WAI values compared to the S5 and S11 feeds. Similarly, in the study by Kannadhason et al. (2011), increasing starch levels from 20% to 40% resulted in a decrease in WAI values by 15.4% - 4.30%.

WSI values

When the water solubility index (WSI) values were analyzed, the fact that there was no increase in WSI values despite the increase in starch amount suggests that other raw material inputs have an effect on these values. The fact that inputs other than fish meal, soybean and wheat flour were constant in all three feed groups explains the effects of soybean on WSI. According to Sorensen (2012), changes in protein sources can cause significant changes in expansion. For example, the addition of soy protein to pure starch leads to an increase in expansion. Since it is known that the increase in expansion is paralleled by an increase in gelatinization, the higher than expected gelatinization in feed S5 can be attributed to the higher soy content compared to other feeds. This suggests that soy compensates for the lack of gelatinization caused by starch deficiency. Similarly, feed S8 contained less starch but more soy than feed S11. This can be seen as a reason for the balance in WSI values. In feeds with lower starch content, the amount of soy is increased to balance the raw material, which positively affects the gelatinization of the feed. In feeds with high starch content, less soy and more fish meal are used to balance the raw material, which negatively affects gelatinization. Narbutaite (2008) investigated the effects of moisture on gelatinization value, WSI and water absorption index (WAI) values in different starch sources and found that increasing moisture significantly affected gelatinization in wheat flour. From this perspective, we can explain that the S5 feed, which is exposed to steam during the extrusion stage, undergoes more gelatinization and therefore has a higher WSI value compared to other feeds. In the study by Kannadhason et al. (2011), increasing starch levels from 20% to 40% resulted in a decrease in WSI values by 31.4% and 11.4%. The fact that there was a statistical difference in all processing steps according to raw metarials and that S11 feed showed the lowest WSI value is similar to this study.

WS values

When examining the Water Stability (WS) values, it is observed that the dry matter loss of the S5 feed is quite high compared to the other feeds. It is expected for the dry matter loss to be higher due to the binding effect of starch molecules. However, studies have reported that soy additives at 42% or higher significantly decrease WS values (Lim and Cuzon, 1994), while wheat flour additives increase the WS value (Hepher, 1969; Balazs et al., 1973). Also, clear relationship related to starch content was observed in terms of WS values between the S8 and S11 feeds.

CONCLUSION

When evaluating the findings obtained from the study, it is evident that the physical quality of the feed is influenced by various factors. These factors include not only the change in the amount of starch but also the type of starch source, its ratio in the ration, and the production process. Additionally, the other raw materials present in the ration, their interactions with each other, and their behavior during the process also play a

significant role. It has been concluded that the amount of absorbed oil does not have an impact on the physical quality of the feed. According to this study, the S8 (30/50) group gave more positive results on feed quality.

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AUTHORSHIP CONTRIBUTIONS

All authors contributed to the idea and design of the study. Material preparation and investigation were performed by Pınar Demir. The writing/editing was carried out by Aysun Kop and Ali Yıldırım Korkut. All authors have read and approved the article.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for this study

DATA AVAILABILITY STATEMENT

All relevant data is in the article.

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Determination of amino acid and fatty acid profiles of bogue (*Boops boops*) fished in the Gulf of Antalya

Antalya Körfezi'nden avlanan kupes (*Boops boops*)'in amino asit ve yağ asidi özelliklerinin belirlenmesi

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Abstract: Our study aimed to establish the monthly changes of bogue fatty acids and amino acids (*Boops boops* Linnaeus, 1758) economically important species during the fishing season. According to the results of the fatty acid analysis of bogue; the highest values were detected for C20:4 ω-6 (arachidonic acid) in December (6.50%), EPA (eicosapentaenoic acid) C20:5 ω-3 in September (5.45%), DHA (docosahexaenoic acid) C22:6 ω-3 in March (16.36%), ΣMUFA (total monounsaturated fatty acid) in April (36.57%), ΣPUFA (total polyunsaturated fatty acid) in November (31.81%) and EPA+DHA in March (19.61%). The highest EPA, DHA and total ω-3 values were observed in March. Amino acid values usually showed important monthly variation ($P<0.05$). EAA (Essential amino acids) such as lysine (4038.5 mg/100g), valine (1126.5 mg/100g) and leucine (1737.5 mg/100g) contents of bogue were detected in February as the highest values. Glutamic acid and aspartic acid from the NEAA (Non-essential amino acid) values were found highest amount in April. Fatty acids and amino acid values, obtained from the bogue samples changed monthly and were generally significant ($P<0.05$).

Keywords: *Boops boops*, fatty acids, amino acids, bogue, season

INTRODUCTION

Amino acids are qualification indicators in fish and crustaceans (Ruiz-Capillas and Moral, 2001). Important amino acids for taste and aroma are glutamic acid, alanine, aspartic acid and glycine (Ruiz-Capillas and Moral, 2004). Fish are important sources of protein in that they contain aspartic acid, glutamic acid, lysine, arginine and leucine amino acids in large amounts (Rosa and Nunes, 2003; Erkan and Özden, 2007). Muscles are the most eaten up and tasty part of fish and include a significant amount of aromatic components and amino acids. Amino acids have important roles in the body improvement and development (Oluwaniyi et al., 2010).

Linoleic acid, linolenic acid, arachidonic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are known as essential fatty acids, and since these fatty acids cannot be synthesized by animal creatures, they must be taken from the diet (Gogus and Smith, 2010). EPA (C20:5, ω-3), decosapentaenoic acid (DPA) (C22:5, ω-3) and DHA (C22:6, ω-3), which are the most important omega-3 fatty acids, are abundant in fish (Gogus and Smith, 2010).

Bogue (from Sparidae), which is known to be distributed in all our seas (Bilecenoğlu et al., 2014; Demirkesen, 2015), is a commercially important fish for countries with a Mediterranean coast (Bogdanovic et al., 2012; Soykan et al., 2015). It is exported to European countries, particularly in winter (Cengiz et al., 2019).

Even though there are studies on the determination of Bogue's fatty acids and amino acids (Passi et al., 2002; Kalogeropoulos et al., 2004; Özogul and Özogul, 2007; Diraman and Dibeklioglu, 2009; Zotos and Vouzanidou, 2011; Ciampa et al., 2012; Prato and Biandolino, 2012; Simat et al., 2012; Morales-Medina et al., 2015; Simat et al., 2015; Miçooğulları, 2017; Uçar, 2020), few studies have been done on the monthly change of nutritional composition. In this study, the monthly fluctuations in amino acids and fatty acids of bogue, caught in Antalya Bay and has economic significance, were examined.

MATERIALS AND METHODS

Sample collection and storage

In the notification numbered 5/1 regulating commercial fishing published by the Ministry of Agriculture and Forestry in 2020, there is no period and length restriction for bogue fishing (No: 2020/20). Despite this, fishermen prefer to fish during the general fishing season to avoid any sanctions during fishing periods. For this reason, sampling studies were carried out monthly during the 2019-2020 (September 1st-April 15th) fishing season. Bogue samples were obtained

from trawlers who fished in Antalya Bay between the 1st of September and the 15th of April. The freshest samples were purchased from fishermen in Antalya Fishing Port and transported to the laboratory (Isparta University of Applied Sciences Eğirdir Faculty of Fisheries Food Processing Laboratory) in iced styrofoam boxes with a ratio of 1/3 ice/fish within 2 hours.

The total length precision of each specimen was measured ±0.1 cm and body weight was measured ±0.1 g. The internal organs of the fish were then removed. The samples were packaged in enough (5 pieces) ziplock plastic bags for each test and labeled, then preserved at -80±1°C (Daihan Digital Ultra Low-Temperature Freezer, South Korea). No distinction was made between males and females in the sampling studies, and the sampling was done randomly.

Identifying fatty acids

Fatty acid analyses were performed in TÜBİTAK MAM according to IUPAC (1981) procedure in duplicate. Chromatographic separation was performed utilizing gas chromatography (GC, Perkin Elmer, Autosystem GLX, Shelton, USA), standard mix (Supelco 18919 F.A.M.E. Mix C4-C24). Fatty acids were defined according to the emergence time of the peaks given by the standards and the values determined as % area in the chromatograms were given as a result.

Identifying amino acids

The amino acid tests of the patterns were performed at TÜBİTAK MAM by Dimova (2003) and Gheshlaghi et al. (2008) reported the High-Performance Liquid Chromatography (HPLC) method was performed in duplicate. The procedure is based on extraction with phenyl isothiocyanate and acetonitrile: methanol: triethylamine solution after acidic hydrolysis is applied to break down the proteins in the sample into amino acid components and read in the UFLC-UV detector. Since tryptophan is entirely degraded as a consequence of acid hydrolysis, it was done by the base hydrolysis procedure. Sulfur-accommodating amino acids decompose right away meantime hydrolyzed with a strong acid solution, therefore they are not evaluated.

A total of 16 amino acids were examined. As a result of the analyses, the 16 amino acids, including methionine, phenylalanine, lysine, valine, leucine, isoleucine, threonine, arginine, histidine, alanine, aspartic acid, glutamic acid, tyrosine, glycine, serine, and proline were evaluated.

Statistical analysis

The data acquired from this research were exposed to analysis of variance (F Test) utilizing the SPSS 16.0 program. The means of the important resources of variance were matched with the Duncan Multiple Comparison Test, with an importance grade of P=0.05.

RESULTS

In our study, the average weight and length of bogue was 37.8±4.46g and 15.4±0.36 cm. It was noticed that seasonal changes in fatty acids obtained from the bogue samples taken regularly every month during the fishing season were usually important (P<0.05). According to results, palmitoleic acid and oleic acid from MUFAs, linoleic acid (except September), arachidonic acid, EPA, DPA, and DHA from PUFAs, C14:0, C16:0 and C18:0 from SFA (saturated fatty acid) were the dominant fatty acids in all months. Statistically insignificant changes (P>0.05) were observed between October-November and January-February for ΣSFA, between October-November and April for ΣMUFA, and between September-December and October-November for ΣPUFA. The highest ΣUNSFA value was observed in November, while the lowest one in December. Σω-3 PUFA, Σω-3 PUFA, Σ UNSFA, ΣUNSFA/ ΣSFA, EPA+DHA and ω-6/ω-3 values showed insignificant changes (P>0.05) between the November and December (Table 1).

The amino acid profile (EAA and NEAA) of bogue is presented in Table 2. There were significant monthly variations in the content of amino acids (P<0.05). While the highest methionine, phenylalanine, lysine, valine, leucine and isoleucine values were found in February, the highest histidine, alanine, threonine, tyrosine, glycine, serine, proline and ΣAA amounts were detected in February. Arginine, asparagine and glutamic acid reached their highest values in April. The lowest phenylalanine, valine, leucine, isoleucine, tyrosine, alanine, glycine, serine and proline values were obtained with April samples (Table 2).

DISCUSSION

Fatty acid values

The fatty acid compositions of bogue ranged from 23.92% to 37.33% SFAs, 17.48 - 36.57% MUFAs and 22.66 – 31.81% PUFAs. The highest fatty acids of bogue were palmitic acid (19.96%) (SFA), oleic acid (31.40%) (MUFA) and linoleic acid (18.39%) (PUFA).

The highest ΣPUFA/ΣSFA value was determined in October (1.32) and November (1.32), and the change of this value according to months was found to be insignificant (P>0.05) among themselves in October–November and January-February-March-April (Table 1).

The PUFA/SFA ratio is an important parameter for nutrition and a good criterion for determining the quality of fatty acids (Aberoumand and Baesi, 2023). The ΣPUFA/ΣSFA rate should be at least 0.45 as a consideration of the tendency of diet to affect the prevalence of coronary heart illness (HMSO,1994). This value of bogue was found above the recommended value in all months. It can be stated that bogue is a good food source in terms of ΣPUFA/ΣSFA. Similar results were obtained in Uçar (2020)'s study with the same species in Mersin Bay.

Table 1. Alterations in fatty acid component of *B. boops* (%)

Fatty acids	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
C6:0	0.06±0.0^{a}	0.00±0.00^{d}	0.00±0.00^{d}	0.02±0.00^{c}	0.00±0.00^{d}	0.04±0.00^{b}	0.01±0.10^{cd}	0.00±0.00^{d}
C8:0	0.06±0.01^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
C10:0	0.11±0.05^{a}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{c}	0.08±0.00^{b}	0.00±0.00^{c}	0.00±0.00^{c}
C12:0	0.19±0.05^{a}	0.04±0.00^{a}	0.04±0.00^{a}	0.06±0.00^{a}	0.23±0.19^{a}	0.14±0.05^{a}	0.04±0.00^{a}	0.04±0.05^{a}
C13:0	0.08±0.00^{bc}	0.03±0.05^{d}	0.03±0.05^{d}	0.11±0.00^{a}	0.09±0.00^{b}	0.08±0.05^{c}	0.09±0.05^{bc}	0.03±0.00^{d}
C14:0	5.55±0.00^{a}	2.70±0.03^{f}	2.65±0.03^{f}	5.75±0.16±^{a}	4.79±0.02^{c}	5.17±0.11^{b}	4.32±0.10^{d}	3.61±0.01^{e}
C15:0	1.25±0.00^{b}	0.43±0.01^{f}	0.42±0.01^{f}	1.39±0.03^{a}	1.04±0.01^{d}	0.80±0.01^{e}	1.20±0.02^{c}	0.45±0.01^{f}
C16:0	19.96±0.05^{a}	15.15±0.07^{d}	15.19±0.06^{d}	17.10±0.35^{c}	16.86±0.03^{c}	18.16±0.25^{b}	18.08±0.21^{b}	15.26±0.07^{d}
C17:0	1.14±0.05^{a}	0.37±0.00^{d}	0.39±0.01^{d}	1.12±0.02^{a}	1.01±0.03^{b}	0.63±0.02^{c}	1.03±0.01^{b}	0.39±0.01^{d}
C18:0	7.86±0.00^{a}	4.50±0.04^{ef}	4.64±0.02^{e}	6.92±0.14^{b}	5.39±0.06^{d}	4.59±0.09^{ef}	6.70±0.65^{c}	4.40±0.03^{f}
C20:0	0.66±0.00^{c}	0.51±0.03^{e}	0.49±0.00^{e}	0.94±0.01^{a}	0.80±0.01^{b}	0.62±0.02^{d}	0.78±0.00^{b}	0.60±0.01^{d}
C21:0	0.11±0.0^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.22±0.01^{b}	0.58±0.57^{b}	1.05±1.05^{b}	0.62±0.01^{b}	2.65±0.02^{a}
C22:0	0.19±0.00^{c}	0.15±0.00^{d}	0.16±0.00^{d}	0.25±0.01^{a}	0.22±0.01^{b}	0.16±0.00^{d}	0.22±0.00^{b}	0.16±0.02^{d}
C23:0	0.05±0.01^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.28±0.00^{a}	0.12±0.09^{ab}	0.12±0.05^{ab}	0.03±0.01^{b}	0.17±0.13^{ab}
C24:0	0.09±0.05^{cd}	0.06±0.00^{e}	0.07±0.01^{e}	0.15±0.01^{b}	0.10±0.01^{c}	0.08±0.00^{d}	0.19±0.01^{a}	0.09±0.0^{cd}
ΣSFA	37.33±0.04^{a}	23.92±0.11^{e}	24.05±0.12^{e}	34.29±0.71^{b}	31.20±0.79^{c}	31.69±1.55^{c}	33.27±0.38^{bc}	27.82±0.26^{d}
C14:1	0.09±0.00^{a}	0.03±0.00^{a}	0.03±0.00^{a}	0.05±0.00^{a}	0.04±0.00^{a}	0.06±0.00^{a}	0.04±0.00^{a}	0.03±0.00^{a}
C15:1	0.04±0.03^{a}	0.00±0.00^{a}	0.03±0.03^{a}	0.02±0.01^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
C16:1	5.63±0.04^{a}	3.57±0.03^{e}	3.55±0.02^{e}	3.88±0.09^{d}	3.53±0.02^{e}	4.33±0.10^{b}	3.20±0.04^{f}	4.06±0.01^{c}
C18:1 ω-9*c*	11.40±0.03^{e}	30.33±0.24^{b}	30.22±0.13^{b}	11.80±0.25^{e}	16.90±0.03^{d}	19.69±0.40^{c}	11.80±0.12^{e}	31.40±0.14^{a}
C20:1	0.91±0.00^{e}	1.64±0.02^{a}	1.61±0.01^{a}	1.23±0.03^{c}	1.31±0.01^{b}	1.25±0.03^{c}	1.02±0.01^{d}	0.23±0.00^{f}
C22:1 ω-9	0.40±0.00^{d}	0.26±0.00^{e}	0.27±0.01^{e}	0.46±0.01^{b}	0.55±0.00^{a}	0.43±0.01^{c}	0.47±0.01^{b}	0.55±0.01^{a}
C24:1	0.62±0.05^{abc}	0.33±0.05^{c}	0.33±0.00^{c}	0.90±0.02^{ab}	0.74±0.00^{ab}	0.56±0.00^{bc}	0.97±0.01^{a}	0.30±0.29^{c}
ΣMUFA	19.07±0.04^{d}	36.15±0.29^{a}	36.03±0.13^{a}	18.32±0.38^{de}	23.07±0.02^{c}	26.30±0.52^{b}	17.48±0.17^{e}	36.57±0.13^{a}
C18:2 ω-6	0.98±0.07^{f}	18.39±0.09^{a}	18.26±0.09^{a}	2.58±0.07^{e}	6.63±0.01^{d}	8.85±0.19^{c}	2.69±0.03^{e}	12.45±0.04^{b}
C18:3 ω-6	0.13±0.01^{a}	0.11±0.00^{bcd}	0.11±0.00^{bcd}	0.10±0.01^{d}	0.12±0.01^{bc}	0.10±0.00^{cd}	0.05±0.00^{e}	0.13±0.01^{ab}
C18:3 ω-3	0.37±0.01^{c}	3.40±0.06^{a}	3.22±0.02^{a}	0.52±0.01^{bc}	0.96±0.19^{bc}	1.24±0.66^{b}	0.67±0.00^{bc}	0.42±0.01^{bc}
C20:2	0.99±0.00^{c}	1.21±0.01^{a}	1.21±0.01^{ab}	0.92±0.02^{d}	1.02±0.01^{c}	1.25±0.03^{a}	0.78±0.02^{e}	1.17±0.01^{b}
C20:3 ω-6	0.17±0.01^{b}	0.13±0.01^{d}	0.15±0.01^{c}	0.09±0.00^{a}	0.13±0.01^{d}	0.13±0.00^{d}	0.10±0.01^{a}	0.18±0.00^{a}
C20:3 ω-3	0.09±0.01^{c}	0.26±0.01^{ab}	0.25±0.00^{ab}	0.02±0.00^{c}	0.26±0.05^{ab}	0.20±0.00^{b}	0.31±0.01^{a}	0.22±0.07^{ab}
C20:4 ω-6	5.40±0.08^{d}	6.40±0.09^{a}	6.48±0.01^{a}	6.50±0.08^{a}	6.06±0.07^{b}	4.55±0.02^{e}	5.77±0.06^{c}	4.62±0.05^{e}
C22:2	0.34±0.00^{c}	0.42±0.01^{b}	0.44±0.01^{a}	0.28±0.01^{d}	0.03±0.00^{e}	0.43±0.01^{ab}	0.01±0.00^{f}	0.03±0.00^{e}
C20:5 ω-3	5.45±0.01^{a}	2.19±0.01^{f}	2.37±0.02^{e}	3.77±0.04^{b}	3.41±0.04^{c}	3.70±0.08^{b}	3.25±0.04^{d}	2.04±0.01^{g}
C22:5 ω-3	2.01±0.02^{a}	0.86±0.02^{f}	0.98±0.01^{e}	1.76±0.03^{b}	1.59±0.01^{c}	1.30±0.03d	1.57±0.01c	1.28±0.01^{d}
C22:6 ω-3	12.09±0.01^{b}	4.28±0.05^{e}	4.35±0.02^{e}	12.40±0.24^{b}	10.70±0.01^{c}	9.27±0.14^{d}	16.36±0.10^{a}	4.26±0.00^{e}
ΣPUFA	25.59±0.06^{e}	31.68±0.12^{a}	31.81±0.16^{a}	25.24±0.46^{e}	26.55±0.20^{d}	27.51±0.19^{c}	28.45±0.18^{b}	22.66±0.02^{f}
TOTAL	81.99±0.14^{c}	91.75±0.52^{a}	91.88±0.40^{a}	77.85±1.55^{d}	80.81±0.58^{cd}	85.50±1.89^{b}	79.20±0.73^{cd}	87.05±0.15^{b}
Unidentified	18.01±0.14^{b}	8.26±0.52^{d}	8.12±0.40^{d}	22.16±1.55^{a}	19.20±0.58^{ab}	14.51±1.89^{c}	20.81±0.73^{ab}	12.96±0.15^{c}
ΣUNSFA	44.66±0.10^{ef}	67.83±0.41^{a}	67.84±0.29^{a}	43.56±0.84^{f}	49.61±0.21^{d}	53.81±0.34^{c}	45.93±0.35^{e}	59.23±0.11^{b}
ΣUNSFA/ ΣSFA	1.20±0.01^{f}	2.84±0.01^{a}	2.82±0.00^{a}	1.27±0.00^{f}	1.59±0.05^{d}	1.70±0.07^{c}	1.38±0.01^{e}	2.13±0.02^{b}
EPA+DHA	17.54±0.02^{b}	6.47±0.06^{f}	6.71±0.03^{f}	16.17±0.28^{c}	14.11±0.05^{d}	12.97±0.22^{e}	19.61±0.14^{a}	6.30±0.01^{f}
ω-3 PUFA	20.00±0.02^{b}	10.98±0.03^{f}	11.15±0.05^{f}	18.46±0.31^{c}	16.92±0.20^{d}	15.70±0.42^{e}	22.15±0.14^{a}	8.21±0.05^{g}
ω-6 PUFA	4.27±0.08^{f}	19.08±0.09^{a}	19.02±0.10^{a}	5.59±0.13^{e}	8.58±0.01^{d}	10.14±0.21^{c}	5.51±0.05^{e}	13.26±0.06^{b}
ω-6 / ω-3	0.21±0.01^{f}	1.74±0.01^{a}	1.71±0.01^{a}	0.30±0.00^{e}	0.51±0.01^{d}	0.65±0.03^{c}	0.25±0.00^{f}	1.62±0.02^{b}
ΣPUFA/ ΣSFA	0.69±0.01^{c}	1.32±0.01^{a}	1.32±0.00^{a}	0.74±0.01^{c}	0.85±0.03^{b}	0.87±0.05^{b}	0.85±0.01^{b}	0.81±0.01^{b}

In the same line, means with different lowercase letters are significantly different (P<0.05).

Table 2. Alterations in amino acid component of *B. boops* (mg/100g)

Amino acids	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Methionine	592.0±2.0^{c}	534.0±1.0^{e}	568.5±1.5^{d}	592.0±1.0^{c}	658.5±0.5^{b}	688.0±3.0^{a}	595.0±4.0^{c}	563.0±3.0^{d}
Phenylalanine	791.0±5.0^{c}	735.5±2.5^{e}	766.5±4.5^{d}	786.0±1.0^{c}	821.5±0.5^{b}	913.0±7.0^{a}	766.5±6.5^{d}	666.0±7.0^{f}
Lysine	3754.0±26.0^{c}	2642.0±14.0^{g}	3874.0±27.0^{b}	3162.5±15.5^{e}	3597.0±18.0^{d}	4038.5±36.5^{a}	3578.0±38.0^{d}	3027.5±35.5^{f}
Valine	1019,0±7.0^{c}	1011.5±2.5^{c}	972.0±4.0^{d}	1027.5±4.5^{c}	1074.0±6.0^{b}	1126.5±8.5^{a}	928.5±7.5^{e}	877.0±9.0^{f}
Leucine	1458.5±6.5^{d}	1426.5±0.5^{e}	1415.0±4.0^{e}	1534.5±13.5^{c}	1583.0±3.0^{b}	1737.5±5.5^{a}	1434.0±9.0^{de}	1345.5±10.5^{f}
Isoleucine	874.5±2.5^{c}	856.0±1.0^{d}	840.5±5.5^{e}	908.5±1.5^{b}	912.5±0.5^{b}	1012.0±5.0^{a}	820.5±2.5^{f}	762.5±4.5^{g}
Threonine	565.5±1.5^{c}	565.5±1.5^{c}	516.5±1.5^{d}	496.5±0.5^{de}	686.5±12.5^{a}	614.5±2.5^{b}	475.5±12.5^{e}	496.5±3.5^{de}
Arginine	597.5±3.5^{g}	572.5±0.5^{h}	819.0±0.0^{d}	704.5±4.5^{f}	888.0±7.0^{c}	956.0±7.0^{b}	775.5±13.5^{e}	1089.5±12.0^{b}
Histidine	618.0±2.0^{b}	539.5±0.5^{d}	569.0±3.0^{c}	377.5±1.5^{f}	648.0±13.0^{a}	542.5±2.5^{d}	444.5±0.5^{e}	440.5±0.5^{e}
Alanine	1096,0±4.0^{f}	1248.5±0.5^{c}	1062.5±2.5^{g}	1203.5±0.5^{d}	1332.5±1.5^{a}	1304.5±5.5^{b}	1113.0±7.0^{e}	1052.5±7.5^{g}
Asparagine	1497.5±8.5^{c}	847.5±0.50^{e}	1495.5±4.5^{c}	1555.5±5.5^{b}	1078.5±5.5^{d}	717.0±2.0^{f}	1500.5±12.5^{c}	2004.0±16.0^{a}
Glutamic acid	3343.0±10.0^{c}	2924.0±2.0^{d}	3341.0±2.0^{c}	3640.5±11.5^{b}	3379.0±3.0^{c}	2481.5±15.5^{e}	3344.0±5.0^{c}	3705.0±28.0^{a}
Tyrosine	663.0±4.0^{c}	616.0±2.0^{f}	646.0±4.0^{d}	659.5±1.5^{cd}	701.0±1.0^{b}	748.0±6.0^{a}	631.0±6.0^{e}	582.5±6.5^{g}
Glycine	1058.0±1.0^{f}	1268.5±2.5^{b}	1005.5±0.5^{g}	1168.5±0.5^{d}	1297.5±2.5^{a}	1204.0±3.0^{c}	1131.5±5.5^{e}	925.5±3.5^{h}
Serine	587.5±3.5^{b}	521.0±0.0^{e}	524.5±0.5^{e}	508.0±6.0^{f}	718.0±6.0^{a}	556.0±2.0^{c}	487.0±8.0^{g}	537.5±3.5^{d}
Proline	676.5±0.5^{f}	770.0±1.0^{c}	645.5±0.5^{g}	751.0±0.0^{d}	822.0±1.0^{a}	814.0±2.0^{b}	730.5±1.5^{e}	615.0±4.0^{h}
Total	19191.5±73.5^{bc}	17078.5±17.5^{e}	19061.5±61.5^{c}	17076.0±16.0^{c}	20197.5±34.5^{a}	19462.5±113.5^{b}	18755.5±124.5^{d}	18689.5±154.5^{d}

In the same line, means with different lowercase letters are significantly different (P<0.05).

Some researchers have studied the fatty acid contents of bogue (Kalogeropoulos et al., 2004; Özogul and Özogul, 2007; Diraman and Dibeklioglu, 2009; Zotos and Vouzanidou, 2011; Prato and Biandolino, 2012; Morales-Medina et al., 2015). Simat et al. (2015) studied the fatty acid amounts of bogue fish kept in natural and near fish cages. These researchers noticed that miristic acid, palmitic acid, stearic acid, palmitoleic acid, oleic acid, EPA and DHA as the dominant fatty acids. In our study, the highest PUFA value is different (Linoleic acid). In studies, conducted by Diraman and Dibeklioglu (2009) and Prato and Biandolino (2012), it was reported that the reason for the differences in fatty acid ratios could be habitat, feeding, age, size, reproductive status, environmental conditions, water temperature, gender, sexual maturity, salinity and season. Özogul and Özogul (2007) declerated that especially water temperature influences lipid content and fatty acid composition of fish muscle to a certain extend.

Fish is the only important source of PUFA for the human diet, especially ω-3 group (EPA and DHA) found in fish are very important for a healthy life and protection from diseases (cardiovascular diseases, colon cancer, immune system disorders) (Briggs et.al., 2017). It is stated by the United States that the total daily intake of ω-3 fatty acids is 1.6 g. Daily EPA + DHA intake is recommended as 0.5 g in infant feeding and 1 g in adults. The American Heart Association, also in the USA, recommends fish consumption as 340 g per week (Erkan, 2013). Ozogul et al. (2011) reported that adequate amounts of EPA and DHA should be taken for a healthy and regular diet. EPA+DHA as can be seen from the results of this study we conducted with bogue, it is understood that this species is a good source of DHA and EPA.

The proportions of ω-3 PUFAs (ranging from 8.21%-April to 22.15%-March) were higher than those of ω-6 PUFAs (ranging from 4.27% in Sep. to 19.08% in Oct.) (Table 1). The ω-6/ω-3 ratio is important for nutrition and 1/1-5/1 ratios are recommended for healthy food (Osman et al., 2001; Zuraini et al., 2006). Ozogul et al. (2011), stated that this ratio is a good indicator in determining the quality of fat, and it was reported by the British Ministry of Health that the ratio in the diet should be below 4 for the prevention of cardiovascular diseases (Zhang et al., 2020). It was decelerated by Moreira et al. (2001) that ω-3 PUFAs not only have a protective effect against diseases but also improve the nutritional value of food. In this study, the ratio of ω-6/ω-3 was found to range from 0.21 to 1.74 for bogue. These results are agree with previous studies and suitable ratios for healthy diets.

Cengiz et al. (2019) reported that the breeding time of fish varies depending on the environmental and ecological factors of their environment, and the breeding period of the bogue; according to different literature, they emphasized the period between January and July. In his study, he stated that the breeding period of the bogue, caught from Saros Gulf was

between March and May. It can be seen in Table 1 that the DHA, Σ ω-3, ΣMUFA and EPA+DHA ratios are high during the breeding periods of this species. It was stated in a study that, fish require higher levels of PUFA, SFA and MUFA as energy sources in physiological processes such as egg production and spawning during reproductive periods (de Souza et al., 2020).

Amino acid values

In our study, the changes in amino acid values obtained from the bogue samples were detected as generally significant (P<0.05). Although their amounts vary monthly (between September and April), lysine, valine and leucine from the EAA, alanine, glysine, glutamic acid and aspartic acid values from the NEAA are seen to be the major amino acids in our study (Table 2). The highest value (4038.5mg/100g) belonged to lysine in February and the lowest one (440.5mg/100g) was histidin in April. The daily essential amino acid amounts needed for adults, teenagers, children and infants are given in the report published by the Food and Agriculture Organization (FAO, 2013). In this report, different values are given for each amino acid according to age limits. According to the report, with the amino acid averages obtained in our study, it is seen that the bogue can meet the required essential amino acid value significantly.

In a study conducted with *Upeneus moluccensis* (Bleeker, 1855), it was determined that the most essential amino acids were lysine and leucine, and non-essential amino acids were aspartic acid, glutamic acid, alanine and glycine. The same researchers stated that the amino acid content varies by month and that the spawning period and nutrition cause this change (Doğan and Ertan, 2017). Especially aspartic acid and glutamic acids are responsible for enzymatic reactions (Özçiçek and Erkan, 2018). Peng et al. (2013) stated that glutamic acid is an important amino acid in cell proliferation. In a study, the major amino acids of sea bream were found as glutamic acid, lysine and threonine, and the amounts of other amino acids are higher in sea bream (Zebel, 2021).

For the investigating the change in nutritional values of anchovy fish during migration, it was reported that glutamic acid, aspartic acid, lysine and leucine are dominant amino acids in all locations in anchovy fish caught in different locations in the Black Sea (Öğretmen, 2022). In a study conducted by Kendler et al. (2023), starry flounder is rich in lysine and leucine from EAA, aspartic acid and glutamic acid from NEAA in September, December and April.

There are numerous studies on the amino acid ingredient of seafood (Kim and Lall, 2000; Özyurt and Polat, 2006; Özden and Erkan, 2008; Adeyeye, 2009; Erkan et al., 2010; Oluwaniyi et al., 2010; Zhao et al., 2010; Özden and Erkan, 2011; Baki et al., 2015; Doğan and Ertan, 2017) and in these studies glutamic acid, aspartic acid, leucine and lysine were found the dominant amino acids. In these studies, it was emphasized that monthly or seasonal changes may be due to age, height, hunting region, spawning season and nutritional changes.

CONCLUSION

It was noticed that the fatty acids and amino acid contents of bogue samples showed monthly changes (between September and April), and these changes were generally important (P<0.05). So, this study revealed that bogue is a good food source in terms of fatty acids and amino acids, especially EAA and ω-3 fatty acids, which are among the basic nutritional components in the sampled period (fishing season).

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AUTHORSHIP CONTRIBUTION

This article was produced from the doctoral thesis of Hasan Cevher titled "Nutritional properties of bogue (*Boops boops* Linnaeus, 1758) fish". Hasan Cevher**:** Research, material preparation, writing. Şengül Bilgin: Research, writing, auditing. Güntekin Doğan: Writing-review.

CONFLICT OF INTEREST DECLARATION

The authors declare that there are no known financial or personal conflicts that could influence their research (article).

ETHICAL APPROVAL

No specific ethical approval was required for this study.

DATA AVAILABILITY

For questions regarding the datasets, the corresponding author should be contacted.

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Investigation of microalgae isolated from different water resources of Türkiye for their biotechnological utilization

Türkiye'nin farklı su kaynaklarından izole edilen mikroalglerin biyoteknolojik kullanımlarının araştırılması

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Abstract: Microalgae are among the important microorganisms for a sustainable world as a source of renewable energy. In this study, three new microalgae were isolated from different regions of Türkiye and identified by molecular techniques. First isolate was *Chlorella sorokiniana* Shihira and Krauss, 1965 which was isolated from Dim River, second was *Pseudochloris wilhelmii* Somogyi et al., 2013 from Tokat and the third was *Tetradesmus obliquus* (Turpin) Wynne and Hallan, 2016 from Tunca River. The maximum biomass of *C. sorokiniana* was 1.02 g/L, 1.86 g/L for *P. wilhelmii* and 0.80 g/L for *T. obliquus*. The chlorophyll (a+b) concentrations were 0.146, 0.278 and 0.181 µg/mL for *C. sorokiniana*, *P. wilhelmii* and *T. obliquus*, respectively. The biotechnological utilization capacities of new isolates were revealed with the support of literature.

Keywords: Biotechnology, *Chlorella sorokiniana*, isolation, chlorophyll, *Pseudochloris wilhelmii, Tetradesmus obliquus*

Öz: Mikroalgler yenilenebilir enerji kaynağı olarak sürdürülebilir bir dünya için önemli mikroorganizmalar arasında yer almaktadır. Bu çalışmada Türkiye'nin farklı bölgelerinden üç yeni mikroalg izole edilmiş ve moleküler tekniklerle tanımlanmıştır. İlk izolat Dim Nehri'nden izole edilen *Chlorella sorokiniana* Shihira ve Krauss, 1965, ikinci izolat Tokat'tan izole edilen *Pseudochloris wilhelmii* Somogyi ve ark., 2013 ve üçüncü izolat ise Tunca Nehri'nden izole edilen *Tetradesmus obliquus* (Turpin) Wynne ve Hallan, 2016'dır. *C. sorokiniana*'nın maksimum biyokütlesi 1,02 g/L, *P. wilhelmii* için 1,86 g/L ve *T. obliquus* için 0,80 g/L olarak bulunmuştur. Klorofil (a+b) konsantrasyonları *C. sorokiniana*, *P. wilhelmii* ve *T. obliquus* için sırasıyla 0,146, 0,278 ve 0,181 µg/mL olarak bulunmuştur. Bu çalışma kapsamında Türkiye'den izole edilen mikroalg türlerinin biyoteknolojik kullanım kapasiteleri literatür desteğiyle ortaya çıkarılmıştır.

Anahtar kelimeler: Biyoteknoloji, *Chlorella sorokiniana*, izolasyon, klorofil, *Pseudochloris wilhelmii, Tetradesmus obliquus*

INTRODUCTION

The rapid increase in the use of existing energy sources has led researchers to search for renewable energy sources. Microalgae is one of the biomasses used as a renewable energy source. Microalgae are living organisms with biotechnological potential. As a general definition, the term "microalgae" includes both eukaryotic algae such as Chlorophyta, Rhodophyta, Charophyta and the only prokaryotic group Cyanobacteria (Barsanti and Gualtieri, 2014). It is known that cyanobacteria, one of the microalgae, formed about 3 billion years ago and filled the earth with O_2 with their photosynthesis ability. In this way, life forms on earth were formed and diversified. Microalgae are at the forefront of renewable energy studies (Mutaf et al., 2023; Özçiçek et al., 2017). In addition, microalgae are used in food additive production (Jacob-Lopes et al., 2019), wastewater treatment (Taştan et al., 2012a), air pollution prevention (Taştan et al., 2012b), energy production (Perendeci et al., 2019) and many other fields.

The extensive use of microalgae in different industries depends on their growth in both fresh and saline waters, ease and speed of cultivation, and their ability to utilize wastewater and different substrates (Coronado-Reyes et al., 2022; Lu et al., 2015). The increase in carbon dioxide (CO_2) emissions is one of the consequences of anthropogenic activities that contribute to increased global warming. Microalgae are promising species for preventing the increase in CO_2 emissions (Taştan et al., 2016) and the utilization of microalgal biomass directly or by converting it into related by-products provides added value.

Compared to plants, microalgae have the advantages of growing much faster and requiring less land (Schenk et al., 2008). For example, while the land required for palm oil production is 2 m^2 year/kg biodiesel, the land requirement for the production of low-lipid microalgae is estimated to be 0.2 m^2 year/kg biodiesel (Mata et al., 2010). Microalgal biofuels are considered third-generation fuels. Microalgae also have the ability to reduce increasing greenhouse gas emissions and in this context, they fix 40% of global carbon emissions. It is also known that some microalgae species contain 70% lipid (Chu, 2017). Biodiesel from microalgae biomass can reduce 78% of CO_2 emissions on a life-cycle basis compared to conventional diesel fuels (Durrett et al., 2008; Sawayama et al., 1995).

Unfortunately, despite the increase in biodiesel production from microalgae, there is a cost barrier to the commercial use of microalgae in biofuel production, and therefore it has not become practical and cannot replace fossil fuels (Babu et al., 2022; Ghosh et al., 2016).

Nowadays, when the conservation of biodiversity has become even more important due to the increasing loss of species in recent years, the main objectives of our study are to isolate different types of microalgae from different freshwater sources of Türkiye, to determine the species at morphological and molecular levels, to calculate and compare the bioenergy of these isolates by kinetic methods and to determine in which areas they are used.

MATERIALS AND METHODS

Freshwater sampling

Freshwater samples were taken from 3 different regions of Türkiye (Figure 1), whose coordinates are given in Table 1, during the summer season. Freshwater samples were collected into 50 mL falcon tubes and immediately transferred to the laboratory environment.

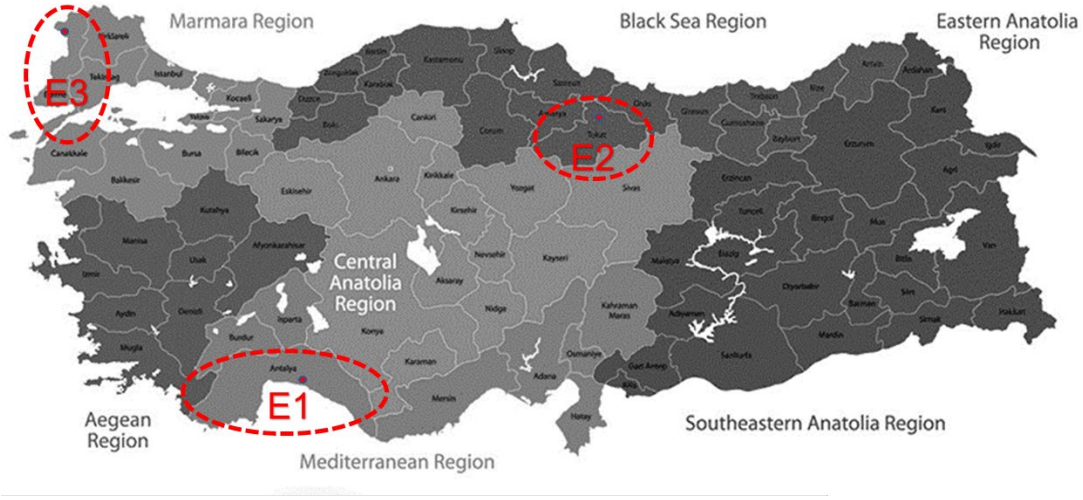

Figure 1. Representation of the regions where water samples were taken on the map of Türkiye

Table 1. Details of the freshwater sources from which microalgae were isolated

Geographical Areas	Freshwater source	Coordinate	Isolate code
Mediterranean Region	Dim Stream Antalya	36°33'08.5"N 32°11'11.4"E	E1
Black Sea Region	Tokat Erbaa village fountain	40°35'31.7"N 36°40'54.4"E	E2
Marmara Region	Tunca River Edirne	41°41'44.5"N 26°33'25.8"E	E3

The medium used in the isolation and cultivation studies was BG11 (Rippka, 1988). This medium is generally used for the cultivation of cyanobacteria and is also frequently used for the cultivation of members of the Chlorophyta group (López-Pacheco et al., 2021; Perendeci et al., 2019). BG 11 medium components are summarized in Table 2.

Microalgae isolation and culture conditions

Freshwater samples from three different geographical regions of Türkiye were centrifuged at 5000 rpm for 10 min to precipitate the microbial biomass. 1 mL sample was taken from the pellet obtained and seeded separately into culture media containing BG11 liquid media in 250 mL flasks. They were then incubated at 25±2 °C under 48 µmol/m²s (2400 lx) light (Figure 2). At the end of the incubation, the microalgae were inoculated into agar petri dishes containing BG11 medium by taking 1 loopful sample. Freshwater samples taken from the source were firstly inoculated in liquid media and then isolated in petri dishes in order to strengthen microalgae growth and thus obtain more biomass. Colonies formed in petri dishes were isolated by micromanipulation by planting them in new petri dishes. In the final stage, the purified microalgae cells were transferred to liquid medium. To confirm axenity, these liquid cultures were also tested for bacterial contamination by plating on bacteriological media.

Table 2. BG 11 medium components

BG11 medium components	
$NaNO_3$	1.5 g/L
Stock solutions	**g/L**
A:K_2HPO_4	0.04
B:$MgSO_4.7H_2O$	0.075
C:$CaCl_2.2H_2O$	0.03
D:Na_2CO_3	0.02
E: Citric acid	6.00
Ferrous ammonium citrate	6.00
Na_2 EDTA	1.0
A5 solution	**mL/L**
H_3BO_3	2.86
$MnCl_2.4H_2O$	1.81
$ZnSO_4.7H_2O$	0.222
$Na_2MoO_4.5H_2O$	0.390
$CuSO_4.5H_2O$	0.079
$Co(NO_3)_2.6H_2O$	0.049

Figure 2. Cultivation of isolates

The isolates were inoculated into horizontal agar tubes containing agar-BG 11 and incubated at 25 ± 2 °C under 48 µmol/m²s (2400 lx) light and stock cultures were obtained.

Identification of microalgae PCR and sequencing

PCR and sequencing of eukaryotic microalgae samples for molecular identification of microalgal isolates were performed by 18S rRNA gene amplification of cultures in the logarithmic growth phase. The 18S rRNA region was amplified using the following primers; forward p23SrV_F: 5'-GGACAGAAAGACCCTATGAA -3' and reverse p23SrV_R: 5'-TCAGCCTGTTATCCCTAG-3' (Sherwood and Presting, 2007). PCR was performed in 50 mL of reaction mix containing 0.2 mM of each primer, 0.2 mM of each dNTP, 1.5 mM $MgCl_2$ and 30 ng of template DNA. Super-HotTaq Taq DNA polymerase (Bioron GmbH, Germany) was the enzyme used for amplification. The initial denaturation step of PCR-amplification was performed at 95 °C for 10 min, followed by 35 cycles of denaturation at 95 °C for 45 s, annealing at 60 °C for 45 s, elongation at 72 °C for 45 s, and final extension at 72 °C for 10 min.

The amplified 5 µL product was analyzed in agarose gel electrophoresis on a 1.2 % agarose gel with 8V/cm ethidium bromide and visualized on a UVP gel imaging system. The amplified PCR product was purified using a QIAGEN gel extraction kit. A total of 18 srRNA amplified products at a concentration of 100 ng/µL were used for sequencing.

Analytical Methods

a. Cell development analysis

Cellular growth of isolated microalgae was determined by calculating optical density (OD_{600}), total dry weight (X), specific growth rates (μ) and maximum productivity (Pmax). Optical density was determined by spectrophotometric analysis of the samples at 600 nm; dry cell weight was determined by weighing the samples after centrifugation at 3421x g = 5000 rpm for 10 min, drying in a sterilizer at 80 ºC for 1 night and then weighing. Specific growth rate (µ) was determined according to the following equation (Ip and Chen, 2005);

In this equation, X_2 (g/L) is the dry cell weight at time t_2 and X_1 (g/L) is the dry cell weight at time t_1.

$$\mu = \frac{lnX_2 - lnX_1}{t_2 - t_1}$$

Maximum productivity was calculated according to the following equation, where X (g/L) is the dry cell weight at time t and X_0 is the dry cell weight at time t_0.

$$Pmax = \frac{X - X_0}{t - t_0}$$

b. CO_2 biofixation analysis

CO2 biofixation rates (F g/g) were calculated according to the following equation (Cheah et al., 2015; Pegallapati and Nirmalakhandan, 2013; Yadav et al., 2015).

$$F = aP\ x\ V$$

a: 1.833 g CO_2, Px: productivity, V: culture volume.

c. Chlorophyll analysis

Chlorophyll analysis was performed according to the method developed by Porra et al. (1989). Accordingly, chlorophyll a was determined at 646.6 nm and chlorophyll b was determined at 663.6 nm. Chlorophyll (a+b) was calculated as total chlorophyll after calculating chlorophyll a and b separately. Chlorophyll concentrations were expressed as µg chlorophyll per milliliter.

d. Data interpretation and statistical analysis

The recorded results were calculated and interpreted using

descriptive statistical analysis (±S.E.). All studies were performed in triplicate. Variances between the data were analyzed in Excel program using %RSD (Relative standard deviation). Before interpreting the data, standard errors were calculated according to the following equation (Kenney and Keeping, 1951);

$$SE = \sqrt{\sigma^2}$$

SE: Standard error, 6: Average of the variable to be analyzed

RESULTS

Identification of microorganisms

At the end of PCR and sequencing studies, according to the results of 18 srRNA, sample E1 was identified as *C. sorokiniana* (NCBI GenBank accession number PP326235) (Shihira and Krauss, 1965); sample E2 as *P. wilhelmii* (NCBI GenBank accession number PP326230) (Somogyi et al., 2013) and sample E3 as *T. obliquus* (NCBI GenBank accession number PP326236) (Wynne and Hallan, 2016). According to the sequences prepared according to the closest species on NCBI

For *C. sorokiniana;*

CTGTTTTATACTGTGAAACTGCGAATGGCTCATTAAATCA
GTTATAGTTTATTTGATGGTACCTACTACTCGGATACCCG
TAGTAAATCTAGAGCTAATACGTGCGCAAATCCCGACTTC
TGGAAGGGACGTATTTATTAGATAAAAGGCCGACCGGGC
TTGCCCGACTCGCGGTGAATCATGATAACTTCACGAATC
GCATGGCCTCGTGCCGGCGATGTTTCATTCAAATTTCTG
CCCTATCAACTTTCGATGGTAGGATAGAGGCCTACCATG
GTGGTAACGGGTGACGGAGGATTAGGGTTCGATTCCGG
AGAGGGAGCCTGAGAAACGGCTACCACATCCAAGGAAG
GCAGCAGGCGCGCAAATTACCCAATCCTGACACAGGGA
GGTAGTGACAATAAATAACAATACTGGGCCTTTTCAGGTC
TGGTAATTGGAATGAGTACAATCTAAACCCCTTAACGAG
GATCAATTGGAGGGCAAGTCTGGTGCCAGCAGCCGCGG
TAATTCCAGCTCCAATAGCGTATATATAAGTTGCTGCAGT
TAAAAAGCTCGTAGTTGGATTTCGGGTGGGGCCTGCCG
GTCCGCCGTTTCGGTGTGCACTGGCAGGGCCCACCTTG
TTGCCGGGGACGGGCTCCTGGGCTTCACTGTCCGGGAC
TCGGAGTCGGCGCTGTTACTTTGAGTAAATTAGAGTGTT
CAAAGCAGGCCTACGCTCTGAATACATTAGCATGGAATA
ACACGATAGGACTCTGGCCTATCCTGTTGGTCTGTA
Similarity Rate %99.87;

For *P. wilhelmii;*

GGAATTTTCCGCAATGGGCGAAAGCCTGACGGAGCAAT
GCCGCGTGAAGGATGACGGCCTATGGGTTGTAAACTTCT
TTTCTCAGAGAAGAATTTTGACGGTATCTGAGGAATAAGC
ATCGGCTAACTCTGTGCCAGCAGCCGCGGTAAGACAGA
GGATGCAAGCGTTATCCGGAATGATTGGGCGTAAAGCGT
CTGTAGGTTGTGTGACAAGTTTTCTGTCAAAGATCAGGG
CTTAACCCTGGGCCGGCAGGAAAAACTATCATGCTAGAG
TTCGGTAGAGGCAGAGGGAATTCCCAGTGGAGCGGTGA
AATGCGTAGATATTGGGAGGAACACCAAAGGCGAAAGCA
CTCTGCTGGGCCGAGACTGACACTGAGAGACGAAAGCG
AGGGGAGCAAAAGGGATTAGATACCCCTGTAGTCCTGTC
TCTTATACACATCTC Similarity Rate: %99.53

For *T. obliquus;*

CTGCTTATACTGTGAAACTGCGAATGGCTCATTAAATCAG
TTATAGTTTATTTGGTGGTACCTTACTACTCGGATAACCG
TAGTAATTCTAGAGCTAATACGTGCGTAAATCCCGACTTC
TGGAAGGGACGTATATATTAGATAAAAGGCCGACCGAGC
TTTGCTCGACCCGCGGTGAATCATGATATCTTCACGAAG
CGCATGGCCTTGTGCCGGCGCTGTTCCATTCAAATTTCT
GCCCTATCAACTTTCGATGGTAGGATAGAGGCCTACCAT
GGTGGTAACGGGTGACGGAGGATTAGGGTTCGATTCCG
GAGAGGGAGCCTGAGAAACGGCTACCACATCCTAGGAA
GGCAGCAGGCGCGCAAATTACCCAATCCTGATACGGGG
AGGTAGTGACAATAAATAACAATACCGGGCATTTCATGTC
TGGTAATTGGAATGAGTACAATCTAAATCCCTTAACGAGG
ATCCGTTGGAGGGCAAGTCTGGTGCCAGCAGCCGCGGT
AATTCCAGCTCCAATAGCGTATATTTAAGTTGTTGCAGTT
AAAAAGCTCGTAGTTGGATTTCGGGTGGGTTCTAGCGGT
CCGCCTATGGTGAGTACTGCTATGGCCTTCCTTTCTGTC
GGGGACGGGCTTCTGGGCTTCACTGTCCGGGACTCGGA
GTCGACGTGGTTACTTTGAGTAAATTAGAGTGTTCAAAGC
AGGCTTACGCCAGAATACTTTAGCATGGAATAACACGAT
AGGACTCTGGCCTATCTTGTTGGTCTGTAGGACCGGAGT
AATGA Similarity Rate: 99.75% was found.

According to the molecular identification studies, the results of the identification of three different microalgae species isolated from three different geographical regions are summarized in Table 3.

Table 3. Molecular species identification results according to geographical regions

Geographical Regions	Freshwater Source	Coding	Type
Mediterranean Region	Dim Stream Antalya	E1	*C. sorokiniana*
Black Sea Region	Tokat Erbaa village fountain	E2	*P. wilhelmii*
Marmara Region	Tunca River Edirne	E3	*T. obliquus*

Culturing of microorganisms

C. sorokiniana, *P. wilhelmii* and *T. obliquus* microalgae were incubated in 250 mL flasks containing 100 mL BG11 medium at 25±2°C under 48 µmol/m²s (2400 lx) light for 7 days. The dry weight values X(g/L) of microalgae recorded during the 3rd and 7th days of incubation period and calculated based on optical density values at 600 nm are shown in Figure 3.

Bioenergy analysis of microalgae

Dry weight (X) (g/L), chlorophyll concentrations chl (a+b) (µg/mL), specific growth rates (μ) (1/d), maximum biomass productivity (Pmax) (g/Ld) and CO_2 biofixation rates (FCO_2) ($mgCO_2/d$) of *C. sorokiniana*, *P. wilhelmii* and *T. obliquus* microalgae are summarized in Table 4.

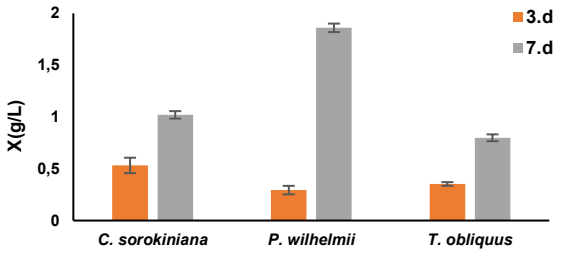

Figure 3. Dry weight values (X (g/L)) of *C. sorokiniana, P. wilhelmii* and *T. obliquus*

Table 4. Dry weight (X) (g/L), chlorophyll concentrations chl (a+b) (µg/mL), specific growth rates (µ) (1/d), maximum biomass productivity (Pmax) (g/Ld) and CO_2 biofixation rates (FCO_2) ($mgCO_2$/d) of *C. sorokiniana*, *P. wilhelmii* and *T. obliquus* microalgae.

	C. sorokiniana	*P. wilhelmii*	*T. obliquus*
X (g/L)	1.02±0.036	1.86±0.041	0.80±0.033
Chl (a+b) (µg/mL)	0.146±0.0052	0.278±0.0061	0.181±0.0073
µ (1/d)	0.162±0.012	0.465±0.059	0.207±0.019
P_{max} (g/Ld)	0.122±0.063	0.392±0.030	0.111±0.059
F_{CO2} ($mgCO_2$/d) (0.1 L)	0.022±0.0008	0.072±0.0052	0.020±0.0060

According to bioenergy calculations, among the three different geographical regions, *P. wilhelmii* microalga isolated from the village fountain of Tokat Erbaa in the Black Sea Region showed higher growth rate of 1.86 g/L, higher chl (a+b) value of 0.278 µg/mL, specific growth rate as 0.465 1/d and productivity as 0.392 g/Ld than the other two isolates under the same environmental conditions. *P. wilhelmii* microalgae was found to be capable of fixing more CO_2 than *C. sorokiniana* and *T. obliquus* microalgae with a value of 0.072 $mgCO_2$/d.

DISCUSSION

Due to their metabolism, microalgae take CO_2 from the atmosphere through photosynthesis, incorporate it into their structures and produce biomass. Isolation and cultuvation of microalgae has been an important area for many years (Ozturk et al., 2019; Atıcı, 2020; Derakhshandeh et al., 2021). Produced biomass is also used in many different areas (Derakhshandeh et al., 2021). Microalgae are therefore a promising feedstock for applications in biofuel production and are recognized as valuable bioproducts. When microalgal fuels are compared to fuels produced from land plants, microalgae can produce 60 times more fuel in the same area. Also, the lack of terrestrial area requirements is an advantage (Skjanes et al., 2013).

In our study, *C. sorokiniana* isolated from water samples taken from Dim Stream in the Mediterranean Region is a very useful microalgae preferred for reducing CO_2 emissions and producing microalgal biomass commercially (Qin et al., 2023).It has also been used in aquatic toxicity assessment studies caused by pollutants such as tetrabromobisphenol A and Cd (II) from e-waste (Liu et al., 2023). It is also known that this microalgae is a suitable species for recycling studies by obtaining lipids and bioethanol from its biomass when grown in the mixed peel extract of potato, banana and sweet lime (Malakar et al., 2023). In another study, *C. sorokiniana* was used for Cd (II) biomineralization from soil (Xia et al., 2023). It was also used to evaluate the ecotoxicity of some antibiotics on aquatic organisms (Li et al., 2023). *C. sorokiniana* is also considered as a highly efficient source for commercial lutein production (Vadrale et al., 2023). Besides *Chlorella* is also used in heavy metal and lipid extraction studies (Atıcı et al., 2008; Derakhshandeh et al., 2019). Additionally, its ability to grow in many different wastes makes it advantageous (Atici and Fidan, 2022).

P. wilhelmii isolated from water samples taken from Erbaa village fountain in Tokat, Black Sea Region is a member of the *Pseudochloris/Picochlorum* genus and has rapid growth rate, extensive range of nutrients and salinity tolerance. (Von Alvensleben et al., 2013; Budiša et al., 2019; Concas et al., 2019). Furthermore, *P. wilhelmii* is a promising microalgae for oil refinery wastewater treatment and high-value biomass production (Blazina et al., 2022).

T. obliquus isolated from water from the Edirne Tunca River in the Marmara Region has been used for lead and cadmium removal (Tafti et al., 2023), bioremediation, CO_2 removal and biofuel production (Selvan et al., 2023) and beta carotene production (Singh et al., 2019).

Among microalgae genera, the genus *Scenedesmus* is the third most studied genus in the world in terms of the number of published literature (Oliveira et al., 2021; Garrido-Cardenas et al. 2018). *Scenedesmus* is one of the most abundant microalgae in freshwater. Species of this genus have single-celled individuals that can form associations of 2 to 32 cells. Mostly, 4-celled ones are common (Oliveira et al., 2021).

T. obliquus has been successfully studied in wastewater treatment and the resulting biomass has been used in renewable energy studies (Oliveira et al., 2021). For example, in a study comparing *T. obliquus* with microalgae such as *C. vulgaris* (34%) and *Oocystis minuta* (27%) in removing sulfate from wastewater, it outperformed other algae by 36% (Ajala and Alexander, 2020). In another study, Ahmad et al. (2019) showed that *T. obliquus* can remove approximately 94% of phosphate from municipal wastewater.

Microalgae cells have also begun to be used in biosensor studies due to their sensitivity to environmental variables (Congur et al., 2022). In this context, the development of biosensors for the detection and monitoring of *T. obliquus* and organic molecules in water has attracted the attention of researchers (Oliveira et al., 2021). Gonzalez and Lorenzo (2019) evaluated the potential of detecting pesticides in water in the cathode they developed using *T. obliquus* cells. As a result, it was determined that *T. obliquus* showed excellent sensitivity and rapid response to environmental changes.

Third-generation biofuels obtained from microalgae, lignocellulosic raw materials, soybeans, corn and other fossil fuels and crops used in biofuel production can be shown as an alternative (Safi et al., 2014; Goh et al., 2019). It has been reported that *T. obliquus* can reach 37.92% ethanol conversion (El-Sheekh et al., 2014) and 90.81% biodiesel conversion (Guldhe et al., 2015) rates and has the potential to produce high amounts of lipids and carbohydrates.

T. obliquus is a microalgae that is also used successfully in the field of health. For example, polysaccharides of *T. obliquus* extracted under different environmental conditions showed antiviral activity against viruses such as *Herpes simplex* virus, *Hepatitis C* virus, *Rotavirus* and *Coxsackievirus* (Singab et al., 2018). Thanks to *T. obliquus* extract, a 40%, 30%, 10% and 40% reduction in *Hepatitis C* virus, *Rotavirus*, *Herpes simplex* virus and *Coxsackievirus* was shown, respectively. It has also been reported that *T. obliquus* extract can also inhibit the growth of 50.4% of human liver cancer cells under in vitro experiments.

CONCLUSION

Microalgae isolation, cultivation and investigation of the use of isolated microalgae in biotechnology studies are important issues in the field of sustainable energy. Within the scope of the study, while microalgae isolated from different freshwater sources in Türkiye were introduced to the literature, bioenergy calculations of these new isolates were also made through kinetic methods. In conclusion, the isolated microalgae are the species that have the potential for rapid growth and biotechnological approaches in the literature. In this context, they have the potential to be used in future studies.

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AUTHORSHIP CONTRIBUTIONS

Eyüp Polat took part in the experiments of the study. Burcu Ertit Taştan was involved in the coordination of experimental studies, interpretation of results, and manuscript writing.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest or competing interests

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

All relevant data is in the article.

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Microplastics in surface water of different beaches in Chattogram coastal area of Bay of Bengal in Bangladesh

Bengal Körfezi (Bangladeş) Çitagong kıyısal bölgesindeki farklı plajlarda yüzey suyundaki mikroplastikler

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Abstract: Microplastic (MP) pollution in aquatic systems poses a great threat, as these tiny particles contaminate water, harm marine life, and may eventually enter the food chain, endangering ecosystems and human health. The purpose of this study was to assess the presence of MPs in surface-level water samples taken from Chattogram Coastal Area of the Bay of Bengal in Bangladesh. A total of 20 water samples were collected from four sea beaches, spanning the period from September to December 2023. A total of 452 MPs were enumerated from the collected water samples, with 29% observed in Kattoli Beach, 26% in Patenga Beach, 24% in Anowara Beach, and 21% in Banshkhali Beach. MPs ranging from 1-5mm in size were identified as the most prevalent in the study areas. Anowara Beach exhibited a dominant composition of fibers (53%), Banshkhali Beach was characterized by particles (55%), and Patenga Beach and Kattoli Beach displayed a high abundance of fragments (65% and 56%, respectively). The abundance of MPs at Kattoli Beach was significantly high ($p<0.05$) compared to other beaches. The pollution load index ranged from 1.25-1.49 with the highest index values at Kattoli Beach. The results from this study could be applied as a guide to efficient environmental management for the long-term health of the beaches by reducing the degree of MP load from the coastal and marine ecosystems of Bangladesh.

Keywords: Abundance, microplastic pollution, coastal water, aquatic pollution

INTRODUCTION

Microplastics (MPs) are plastic particles that are smaller than five millimeters in size (GESAMP, 2016; Kawsar et al., 2024). MP figures are present everywhere in the marine ecosystem, even in the most pristine places, like the deep sea, they have raised worrisome concerns about the health of marine life and the ecological balance. Plastic is a desirable material to utilize because of its durability (Barnes et al., 2009). In the surface ocean alone, there are thought to be more than five trillion plastic particles floating about, with over 90% of these particles being categorized as MPs (Banik et al., 2022). MP pollution has evolved into a transboundary, complex, social, and environmental issue of the twenty-first century that threatens not just marine biodiversity but also humankind. MPs have a low density and can be dispersed easily by wind and water, sometimes traveling thousands of kilometers from their point of origin and remaining in the environment for many years (Kawsar et al., 2024).

Even though plastic has many positive social effects, there is growing environmental concern over this valuable resource (Andrady and Neal, 2009). They also function as distributor of pathogens, carrier of heavy metals and other toxic substances that lead to various health problems (Alengebawy et al., 2021).

The primary sources of these MPs were either marine (transportation, fishing, and shipping) or land-based (personal care items and cosmetics, washing of synthetic clothing, tourism, and industrial activities) (Browne et al., 2011; Rillig, 2012). Waste made of plastic contamination is one of the main ways that humans are affecting the environment and causing a huge threat to marine life (Derraik, 2002). Particularly coastal nations produced roughly 275 million tons of plastic waste and about 3–5% of them are estimated to have ended up in the ocean (Jambeck et al., 2015). Bangladesh generates an estimated 16,000 tons of urban waste each day, growing by 7.5% yearly (Bahauddin and Uddin, 2012). River discharges, tourism, industrial effluents, roadway dust (car tires, grease, etc.), sewage disposals (effluents), and nearby hotels, motels, and restaurants are some of the possible sources of plastic debris in the coastline region of Bangladesh (Browne et al., 2011; Achary et al., 2021; Hossain et al., 2022; Kawsar et al., 2024).

Bangladesh is a densely populated country and the northeastern region of the Bay of Bengal is highly susceptible to MP pollution due to its geographical location and the socioeconomic activities of the area. MP concentrations are much higher in this area. There are multiple hotspots of MP pollution in the Bay of Bengal, including the coasts of Chattogram, Cox's Bazar, and the Sundarbans mangrove forest. Marine ecology is threatened by deposition of MPs, which could result in the tropic transmission of MPs. According to research by Achary et al. (2021), MP was commonly observed on beaches around the Bay of Bengal's coastline, indicating that MP could be transported to the bay directly by discharges from coastal activities. According to Hossain et al. (2022) and Rakib et al. (2022), there is also a lot of shipping traffic in the Bay of Bengal, which contributes to MP pollution. Natural reasons also contribute to the increased rate of MP pollution, even if human activity is the primary cause of it. It was discovered by Law et al. (2014) that plastic waste can be carried from land to water bodies by natural disasters like floods, storms, and tsunamis. Coastal erosion and the weathering of plastic debris on beaches were identified by Jabeen et al. (2017) as other significant pathways for the introduction of MPs into the Bay of Bengal. According to Hossain et al. (2022), a daily estimated 61.3×10^9 items of MPs are released into the Bay of Bengal through the complex riverine and estuarine systems. MP pollution is rising quickly for a variety of causes, it is imperative to design strict and workable intervention strategies to minimize MP pollution and maintain a secure and healthy marine ecology. However, monitoring of MP abundance and pollution in surface waters on different beaches of coastal regions in Bangladesh has not yet been studied. Hence, the objective of the study was to determine the scenario of MP pollution, types, and abundance, in the most popular coastal beaches of Chattogram in Bangladesh to establish effective management of plastic pollution and monitor progress toward achieving sustainable development goals.

MATERIALS AND METHODS

Sampling sites

Chattogram Coastal Area is located on the eastern Bay of Bengal with coastline up to 100 km. It is oriented northeast to southeast. Two major estuarine rivers (Karnaphuli and Sangu) are connected with this coastline. This research was carried out at four sites (Banshkhali, Anowara, Patenga, and Kattoli Beaches) towards the littoral of Bangladesh, primarily in the Chattogram district which are well-known for both recreational activities and the disposal of municipal waste via the Karnaphuli River and other drainage systems (Rahman et al., 2023). The location of the sampling sites and the geographical coordinates are shown in Figure 1. All sampling stations are located near urban areas and harbors. The selection of sampling sites was strategically determined based on their relevance to diverse human activities, encompassing tourism, fishing, urban development, and industry (Table 1). Ship breaking activities are running at this study area near Kattoli Beach (Rahman et al., 2023).

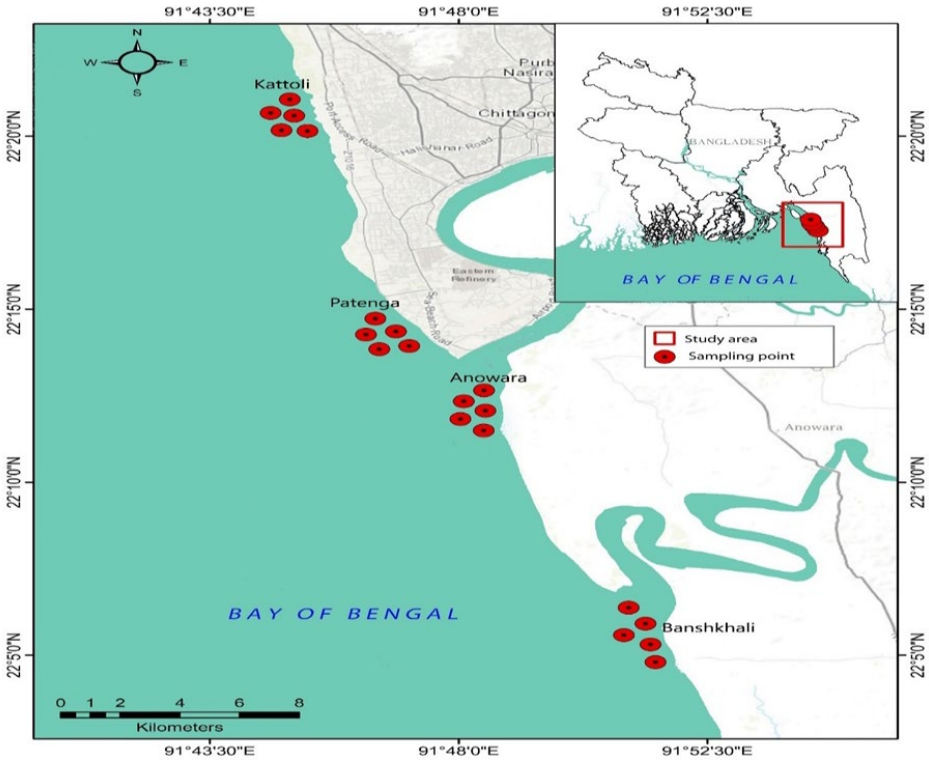

Figure 1. Study area map indicating four sampling sites (each circle indicates sampling point)

Table 1. Visual characteristics of four sampling sites based on their human and industrial activities

Site	Geographic position	Characteristics
Banshkhali Beach	22°03'27" N, 91°51'06" E	It is the port area with a long sandy beach with various beach activities (tourism).
Anowara Beach	22°10'44" N, 91°47'33" E	The mouth of the Karnaphuli River is one of the most secluded and relatively clean areas of the province, the habitat of many birds and turtles in the province, with mangrove forests, relatively low water wave, mostly muddy and sandy areas.
Patenga Beach	22°13'42" N, 91°46'13" E	Recreational business area, more pollution than the urban type and the traffic of commercial and fishing vessels, no agricultural pollution, high volume of passengers and maritime trade, lack of oil and gas industries.
Kattoli Beach	22°14'46" N, 91°44'55" E	The only international cricket ground in Chattogram is located here. Another name for this beach is Jalepara Beach as it is the supplier of fish and shrimp. It is the commercial vessel traffic area and the majority of the urban area and a relatively suitable index for comparison with the relatively clean area and the highly contaminated area of Chattogram. The ship breaking station is located nearby.

Collection and preservation of MPs from water samples

MPs from water were taken from the Chattogram Coastal Area by using Neuston net sampler with a mesh size of 50 µm following Zhang et al. (2020) which is laboratory methods for the analysis of MPs in the marine environment from the surface water of all sites. Water samples from the coastal water were collected with a haul time of 0.5 to 1 h and an average hauling speed of 2 knots at about 5-10m depth with a local engine boat. Water samples were collected from September to December 2023. For the purposes of this investigation, a total of 5 specimens of each site were utilized. As a result, 20 surface water samples were taken from 4 sampling sites. Every sampling point was maintained at a distance of roughly 1 to 1.5 kilometers for each site. For one specimen, three replications were performed. A rigorous random sampling approach was applied to increase the authenticity and dependability of the investigation outcomes by reducing bias and increasing the possibility of a sample that is representative of the larger population. Following collection, each intense MP sample was put into a 500 ml glass bottle, which had been filled with distilled water and washing solution after being cleaned three- or four times using sample water. Every sample was gathered all day long. The sample vial was then taken to the lab for additional analysis after being correctly labeled with the name of the site, the time, and the date. A 50 µm mesh steel sieve was used to filter each sample. To prevent contamination, distilled water was used to wash every residue that remained on the sieve after sieving. The protocol is summarized in Figure 2 according to Masura et al. (2015).

Wet peroxide oxidation (WPO)

The analysis of plastic debris as suspended solids in water samples obtained using a surface net can be done using this method. Hard plastics, soft plastics (such as foams), films, line, fibers, and sheets are examples of plastic materials. To isolate the proper-sized solid material, the method entails filtering the solids collected in a 0.335 mm surface sampling net (such as a manta net for surface water tows) through 5.6-mm and/or 0.3-mm sieves. To find the sample's mass of solids, the material that had been sieved was dried. To break down labile organic matter, the solids were put through wet peroxide oxidation (WPO) with a Fe (II) catalyst present. Plastic waste remained consistent. Density separation in NaCl (aq) was applied to the WPO mixture to separate the plastic debris by flotation. A density separator was used to separate the denser undigested mineral components from the floating solids. To find the concentration of MPs, the floating plastic debris was gathered in the density separator using a specially made 0.3-mm filter, allowed to air dry, and then the plastic material was taken out and weighed (Masura et al., 2015).

Flow diagram for the analysis of MPs

According to Masura et al. (2015) the flow diagram was maintained during the study period to identify the MPs in the water samples.

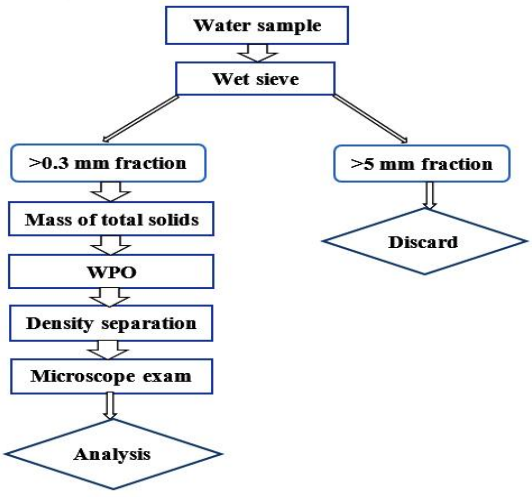

Figure 2. Diagram showing the flow for analyzing MPs in aquatic samples

Categorization of MPs

Biological Binocular Microscope Xsz-107bn Classical Model for laboratory was used to study total count and MP characteristics in each sample after filtration. The objects were evaluated visually, with descriptions provided based on their maximum dimensions, color, and shape (Hidalgo-Ruz et al., 2012; Lusher et al., 2013). According to Hossain et al. (2019), MPs were classified into three sizes in this study, i.e., 0.5mm,

0.5mm to 1 mm, and 1–5 mm. Seven distinct colors were used to categorize MPs: Red, Green, Blue, Black, Yellow, Brown, and White. Five distinct shapes were identified for MPs: irregular, round, angular, elongated, and filamentous. This study categorized MPs into three types: fiber, fragment, and particle followed by Li et al. (2015).

Quality control

In MP analytics, contamination from airborne particles and reagents is a concern. MPs can cause difficulties with quality assurance because they can be found in reagents used in the digestion of organic matter, laboratory equipment, the laboratory environment, and distilled and ultrapure water (Barrows et al., 2017; Prata et al., 2021). Throughout the entire study, including the collection of water samples, their transportation to the laboratory, and their preservation, care was taken. The laboratory was cleaned, and any necessary lids or covers were put over the samples. For sampling, dissection, preservation, alkaline digestion, and filter paper analysis, only glass and stainless-steel equipments were utilized. 70% alcohol that had been prefiltered was used to clean the laboratory. Before being used, filter papers were checked under a microscope for any airborne contaminants.

Interpretation techniques

Li et al. (2021) stated that PLI (Pollution Load Index) can be used to evaluate the degree of contamination generated by the occurrence of MPs in environmental samples. The contamination factor (CF) for every sampling site needs to be determined using the following Shekoohiyan and Akbarzadeh (2022) formula to estimate the PLI.

$$CFi = \frac{Ci}{Coi}$$

Where C_i is the abundance of MP at each sampling point, Coi is the background value estimated as the lowest mean (59.71 particles/kg) MP abundance from the published literature. The MP-PLI can be calculated using the following equation:

$$MP\text{-}PLI = \sqrt{CF}$$

Statistical analysis

SPSS version 22 was used in the study for statistical analysis. When doing statistical analyses, the data distribution was taken into consideration. As the dataset exhibited a normal distribution (assessed through Shapiro-Wilk test, $p>0.05$), a one-way analysis of variance (ANOVA) was used to determine whether there were any variations in the abundance of MPs in different beaches and also that were statistically significant ($p<0.05$) or not statistically significant ($p>0.05$) followed by Tukey post hoc test.

RESULTS

Spatial distribution of MP abundance

The sampling beaches were Banshkhali, Anowara, Patenga and Kattoli. A total of 452 MP items were quantified from the study area. The highest MPs were found at Kattoli Beach (29%) and the lowest was at Banshkhali Beach (21%) (Figure 3). The abundance of MPs was significantly higher ($p<0.05$) in Kattoli Beach, followed by Patenga, Anowara, and Banshkhali Beach (Figure 4).

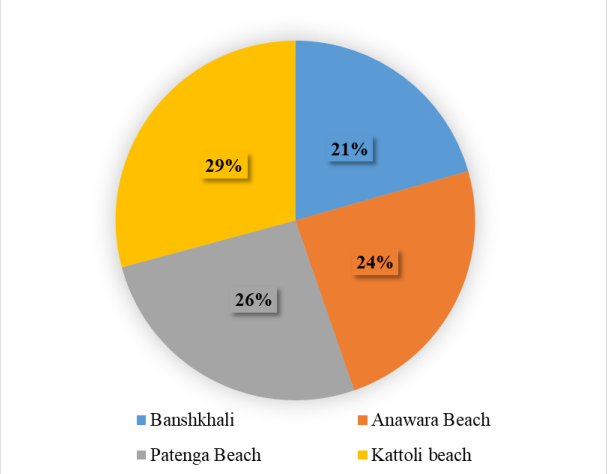

Figure 3. Distribution of total MPs (%) quantified from the water of selected study area

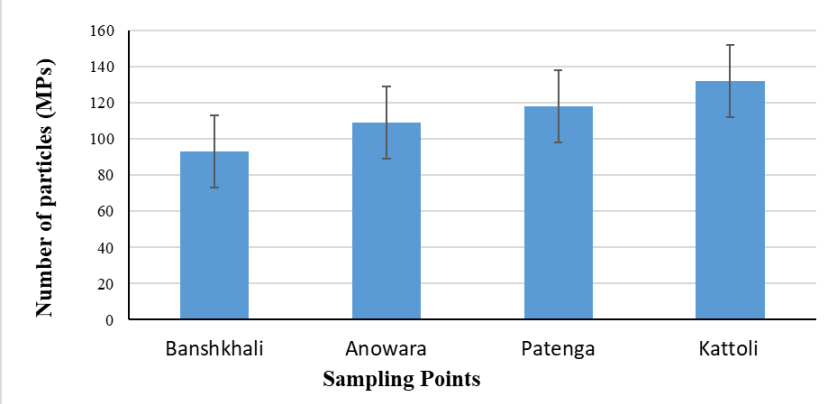

Figure 4. Abundance of MPs in the different areas

Type, shape, color, and size of MPs

Among the samples, three different morphologies of MPs were recorded where 47% fragment, 32% fiber, and 21% particle were noted. Fragment type was dominant in Patenga Beach and Kattoli Beach composing 65% and 56% respectively in these two sites, while fiber was recorded maximum at Anowara Beach (53%), and particle was the highest groups at Banshkhali Beach (55%) (Figure 5-A). Shapes and sizes both were highest in Anowara Beach and lowest in Kattoli Beach. Dominant MP shapes were elongated (35.75%) and sizes were 1-5mm (62.25%) (Figure 5-B and 5-D). Among the collected water samples, white color were dominant (40.5%) followed by brown (28%), red (12%), both green and black (5.75%), blue (5.25%) and yellow (2.75%) (Figure 5-C).

MPs pollution load index (MPs-PLI)

The PLI can be used to determine the extent of MPs pollution in various situations. In the surface water samples, the MPs-PLI standards for the sampling locations vary from 1.25 to 1.49. According to Table 2, Kattoli Beach had the highest PLI, followed by Patenga, Anowara, and Banshkhali Beach. When the PLI value is less than 10, MP pollution is regarded as having no risk (level I), and when it is between 10 and 20, MP pollution is regarded as having minimal risk (level II) (Gholizadeh et al., 2024). All PLI values in the study sites were below 10, indicating that the area is not currently at risk.

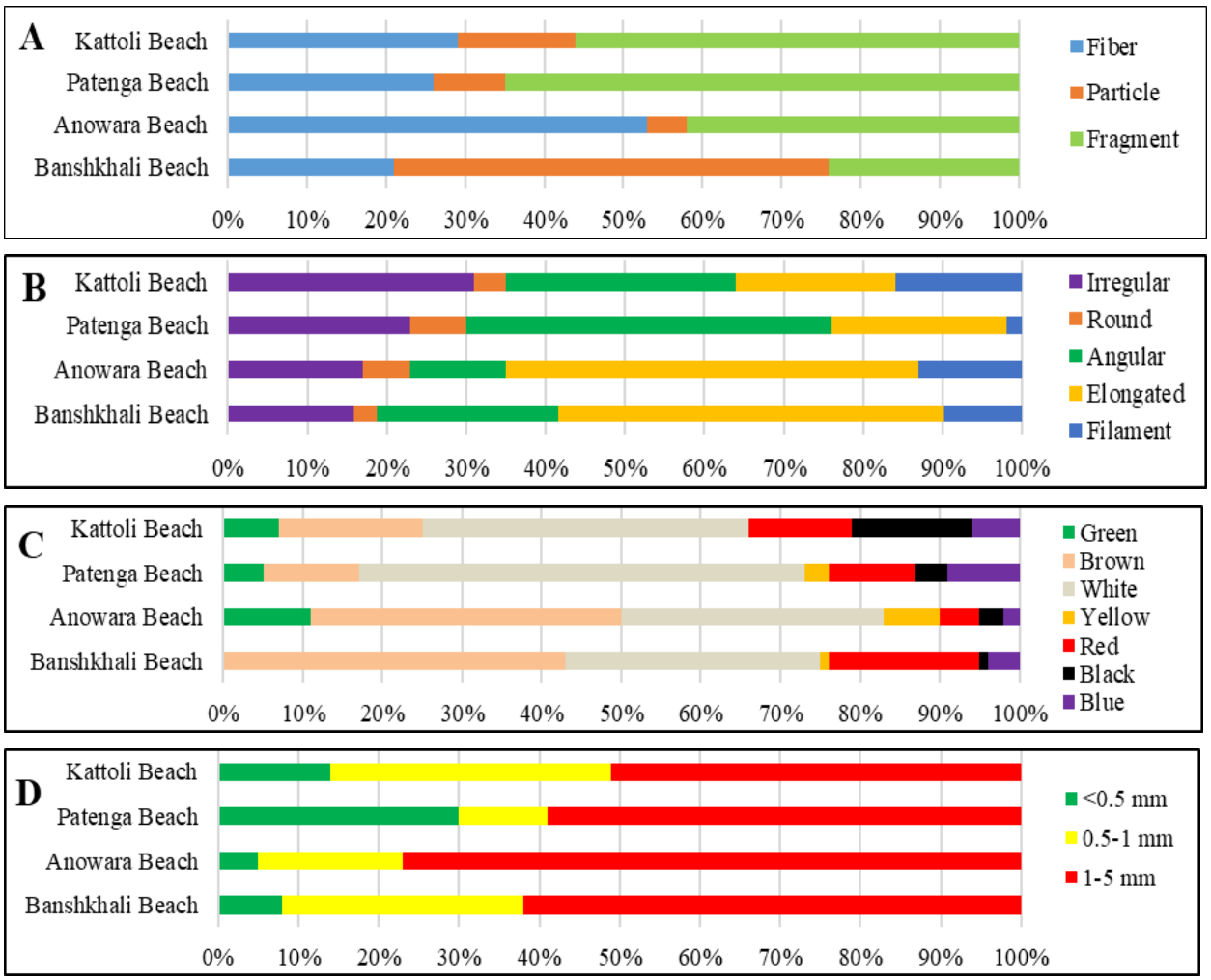

Figure 5. Percentages of types (A), shapes (B), colors (C), and sizes (D) of MPs in water of Chattogram Coastal Area

Table 2. Findings from the risk assessment for MPs in beach water samples

Sampling sites	CF	PLI
Banshkhali Beach	1.56	1.25
Anowara Beach	1.83	1.35
Patenga Beach	1.98	1.41
Kattoli Beach	2.21	1.49

DISCUSSION

Abundances and characteristics of MPs in water

The presence of MPs in water is now a significant environmental concern leading to various negative impacts on biota, ecosystems, and potentially entering the food chain, posing risks to human health (Kawsar et al., 2024). According

to Coyle et al. (2020), marine plastic pollution is an artificial material that originates from two sources: either land sources, which contribute to 80% of marine waste, or coastal practices such as accidental loss or illegal dumping by fishers while fishing or other activities. MPs are a growing contaminant on Bangladeshi beaches and coastal areas (Mia et al., 2024). It is known to be a delayed material in sediment and water. According to this study, the average MP concentration was 22.60 items/m^3. The Kattoli Beach area had the largest number of MPs in the water samples (26.40±1.44 items/m^3), while the Banshkhali Beach area had the lowest number of MPs (18.60±0.69 items/m^3). The following is a sequence of the total concentration of MPs in water samples of coastal beaches in Chattogram: Banshkhali < Anowara < Patenga < Kattoli. The MP concentration was found to be less than the values reported in the Asa River (130±27.84 items/L) and the Awano River (132.80±15.3 items/L) in Japan (Kabir et al., 2021). A comparison of the abundance of MPs in surface water from different samples around the world is shown in Table 3.

Table 3. An assessment of research on the abundance of MPs in water in the world

Study Site	Sample Type	MPs Abundance	References
Bohai Bay, China	Water	788.0±464.2 items/m^3	Wu et al. (2019)
Sürgü Dam Reservoir, Türkiye	Water	(106.63 to 200) items/ m^3	Turhan (2021)
Guangdong Coastal Areas, South China	Water	850 to 3500 items/L	Li et al. (2021)
Chabahar Bay, Iran	Water	218±17 particles/L	Hosseini et al. (2020)
Persian Gulf, Iran	Water	1.67×104 particles/km^2,	Gholizadeh et al. (2024)
KarnaphuliRiver, Bangladesh	Water	2.11±1.15 items/L	Hossain et al. (2022)
Saint Martin Island, Bangladesh	Water	0.074–0.181 items/m^3	Al-Nahian et al. (2022)
Pashur River, Bangladesh	Water	2.66×103 particles/L	Nawar et al. (2023)
Coastal Beaches, Bangladesh	Water	22.6±3.27 items/m^3	Present study

The first sampling was done at the area of Banshkhali Beach which is a remarkably busy area as it is one of the longest sea beaches after Cox's Bazar and tourists come from various regions to visit the beach and appreciate its prettiness At this sampling site, we found the least number of MPs (18.60±0.69 items/m^3) in water trials due to the high tidal action and it is also indicating that the MPs capacity in this region can change rapidly due to wind, wave, current and bottom settlement of MPs (Mia et al., 2024). At Anowara Beach, the second sampling location, a relatively higher abundance (21.80±0.86 items/m^3) was detected. This area is moderately polluted because of both anthropogenic activities and tourism related activities. Moreover, the wave action is also low in this area. Urban discharges coming through the Karnaphuli River is the major evident of domestic plastic pollution. The third and fourth sampling sites which were selected at the Patenga Beach and the Kattoli Beach areas, respectively which had significantly greater concentrations (p<0.05) of MPs in water than the other two sites. The abundance of MPs in these two areas was 23.60±1.36 items/m^3 and 26.40±1.44 items/m^3, respectively. The most polluted region was identified in Kattoli Beach mainly because of waste from the port and fishing activities which are thrown into the surrounding areas at random. The rural fishers use plastic nets to catch aquatic animals (fish and shrimp). The concentration of MPs in this sampling site is heightened by the tiny plastic particles and broken nets (Ta et al., 2022). Both locals and visitors are unaware of the harmful effects of plastic. As a result, they make use of polyethylene, plastic bags, and other readily available and affordable plastic materials which cause pollution. Ineffective trash management at this sample location led to an increase in pollution through MPs. Ship breaking activity is another prominent cause of MP pollution in this area. Most of the ship breaking activities are performed in the open beach sediment from where the plastic particles enter into ocean water and pollute the water body. The four polymers (polyurethane, nylon, polystyrene, polyester, and glass wool) were identified in extracts from sediments in the Alang-Sosiya ship-breaking yard, India (Reddy et al., 2006). Less tourism and more fishing, along with a ship breaking station, results in a significant volume of waste being dumped in that area.

Categories of MPs

In this study, three distinct groups of MP sizes were found. Among them MPs sizes smaller than 0.5 mm being the most typical. A total of 249 MP particles were recognized in the water sample with 1-5 mm size (Figure 5-D). The least number of MPs were found in <0.5 mm size which was 57 particles in total. The analysis's findings are in line with those of prior research (Zhao et al., 2019) that discovered that surface waters primarily contain smaller sized MPs. However, numerous hydrodynamic features such as wind, current, wave, and tidal action, as well as upright mixing of the aquatic environment can reason the bigger MPs elements to break down into small pieces, leaving the smaller ones fluctuating in the surface water (Yang et al., 2023).

Diverse types of MPs were observed in the samples of beach areas (Figure 6). In the current investigation, three dissimilar types of MPs were isolated from water. Fragments were mostly found (46.75%), followed by fibers (32.25%) and particles (21%). Most fragments were found in the Patenga Beach. This indicates that the number of fragments in water is increasing because of both anthropogenic and tourism related activities. Numerous investigations revealed that surface water had a large number of fibers and fragments (Aliabad et al., 2019; Nabizadeh et al., 2019). Fragment particles are the result of the decay of plastic particles (Khaleel et al., 2023).

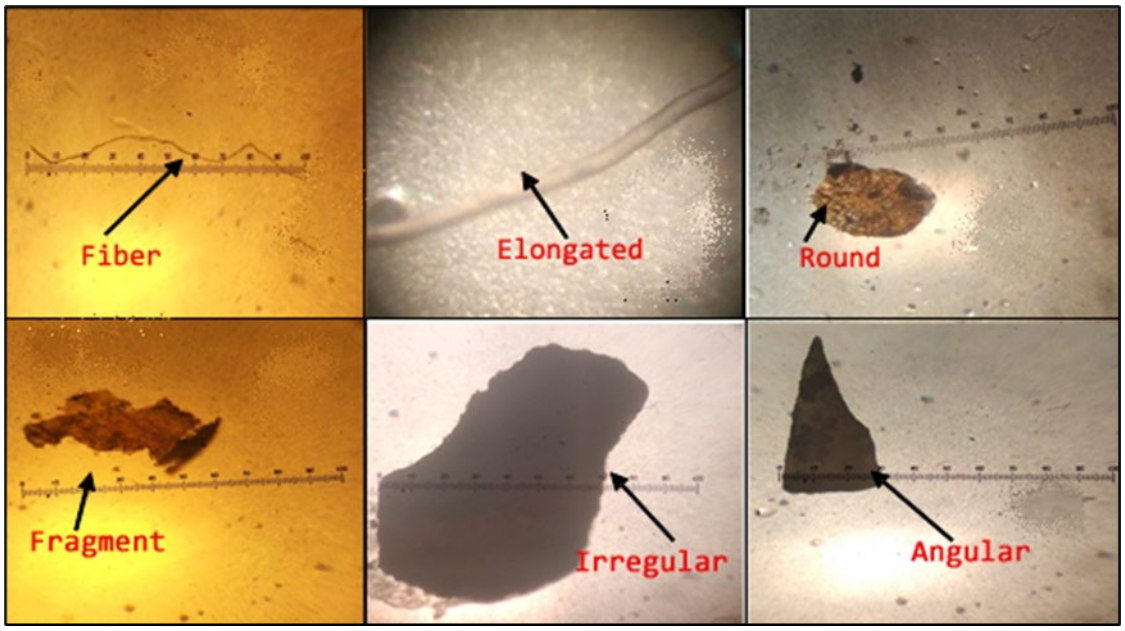

Figure 6. MPs images of different shapes and types

They are often produced from clothing which are made of synthetic materials and from the tearing of fishing nets and ropes (Jaini and Namboothri, 2023). Numerous studies on MPs in Tamil Nadu, India's water have shown similar kinds of results, with the primary causes of the high concentrations of MPs being associated with a range of manufacturing, fishing, and tourism-related activities. According to Jeyasanta et al. (2020), there is a direct link between the quantity of synthetic garbage produced and the quantity of fishing and entertaining actions. Numerous secondary MPs with asymmetrical shapes are released from various packaging materials, including trash, polybags, milk cans, and plastic bottles (Wang et al., 2019). Detected MPs were mostly elongated at Banshkhali Beach (49%) and Anowara Beach (52%) followed by irregular, round, angular and filament shape. At Patenga Beach, angular shape was recorded maximum (46%), and irregular shape was recorded maximum at Kattoli Beach (31%) (Figure 5). The percentage of different shapes of MPs are sequenced as follows: elongated>angular>irregular>filament>round.

Water samples from several sites showed a varied blend of colors. Most of these come in shades of brown, red, yellow, black, and green. Even still, the majority of colors in each sample were white and brown. 40.5% of MPs were determined to be white, and 28% to be brown. According to numerous other investigations, fragments are primarily white in color (Al-Nahian et al., 2023). Most of the trials were clear, but there were also those that had nearly the same percentage (5.75%) of green, black, and blue. In the samples, a fraction of less than 3% of the color yellow was discovered. The third most prevalent color, red, was at 12%. According to some studies, plastic particles can be categorized as "colorful" or "non-colorful". Some of the researchers discovered that most of the colors in MPs were white or transparent, others observed that blue and red colors were more prevalent (Deng et al., 2021; Duong et al., 2023). The particles may originate from rinses used in fishing gear, crafts, and wrapping, as well as synthetic belongings, polyethylene, and other plastic ingredients that tourists may have discarded (Aliabad et al., 2019).

Although there have been efforts to study the abundance and pollution of MPs, there are still many scientific questions that need further investigation in subsequent studies. Plans for environmental management that address MPs and related pollutants must be implemented for the Bay of Bengal's coastal beaches. Additionally, they must set up an extensive, long-term monitoring system. To protect the ecosystem and marine biodiversity, however eco-friendly structures and methods must be developed. Future research should focus on separating and identifying MPs in sediment and soil. For a detailed understanding of the prevalence and nature of pollution, characterization of MPs is essential. Future studies must concentrate on the identification and determination of the specific polymer types that make up MPs. This would enable researchers to identify the precise substances causing MP pollution in coastal areas and provide important latest information about the origins and possible dangers of these polymers. The effects of MPs on sediment, water, human health, biota, and the marine ecosystem must be thoroughly examined. Future studies ought to concentrate on decreasing plastic usage, enhancing disposal techniques, and lowering the number of MPs that enter the marine environment to reduce MP pollution at its source. Although concerns about marine pollution are increasing, little attention has been paid to the possible effects of nanoplastics on marine ecosystems. To effectively investigate the effects of nanoplastics on these crucial environmental regions, new, eco-friendly methodologies must be developed to achieve the Sustainable Development Goals.

Research gap

To assist the policymakers in making decisions regarding the prevention of plastic pollution in Chattogram's well-known beach areas, the current study was designed. The abundance of MPs indicates the problem, but to fully comprehend the fate of these particles and their effects on human health and marine life, proper characterization of plastic polymers is necessary. MP ingestion and its effect on aquatic biota, fish, mammals, waterbirds, and plankton, particularly suspension filter-feeding species (lungworms, mussels, and sea cucumbers) are becoming increasingly concerning (Sussarellu et al., 2016). Furthermore, detrimental polymers specific to an animal or even an organ can be identified via polymer identification. On the other hand, monsoon-related increases in rainfall will effect on the estimated monthly inflow of plastic from rivers into the ocean. According to research by Weideman et al. (2020), the average concentration of MP was slightly greater during the wet season (2.1±6.9 particles/L) than it was during the dry season (1.3±2.5 particles/L). However, collecting data from a single season is insufficient to accurately depict the seasonal fluctuations in concentrations. To better understand the scope and effect of MP pollution in Bangladesh and to guide the development of effective mitigation approaches, it is imperative to solve the research gap.

CONCLUSION

The presence of MPs in the Chattogram Coastal Area of the Bay of Bengal is evident, with significant variations in abundance among the beaches. The high abundance of MPs, particularly at Kattoli Beach, highlights the urgent need for targeted interventions to mitigate plastic pollution in these areas. The fluctuating composition of MPs observed in different beaches underscores the diverse sources and pathways of plastic debris entering the marine environment. The pollution load index values suggest that the beaches in the Chattogram Coastal Area are experiencing low level of plastic pollution, but have a potential threat to marine ecosystems. To address this issue, reducing plastic use, promoting recycling, and increasing awareness are essential steps. Government initiatives and community involvement are crucial in protecting the coastal ecosystem for future generations. These findings emphasize the importance of continued monitoring and management efforts to safeguard the health and integrity of coastal and marine ecosystems in Bangladesh.

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AUTHORSHIP CONTRIBUTIONS

Rimu Das: Conceptualization, Methodology, Writing- Original draft preparation; Debasish Pandit: Data analysis, Validation, Writing- Review and editing; Md. Wahidul Alam: Investigation, Writing- Review and editing; Md. Shah Aziz: Project administration, Writing- Reviewing and Editing; Joyanta Bir: Validation, Writing- Reviewing and Editing; Md Mehedi Hassan: Writing- Reviewing and Editing; Mohammad Rokan Uddin: Resources, Writing- Reviewing and Editing; Md. Habibur Rahman: Supervision, Funding acquisition, Writing- Reviewing and Editing. Ismot Zereen: Writing- Reviewing and Editing.

STATEMENTS AND DECLARATIONS

I declare that the authors have no competing interests as defined by the journal, or other interests that might be perceived to influence the results and/or discussion reported in this paper**.** The results/data/figures in this manuscript have not been published elsewhere, nor are they under consideration by another publisher.

ETHICAL APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Fish availability, market conditions, and livelihood status of traders in a dry fish market in northern Bangladesh

Kuzey Bangladeş'de bir kuru balık pazarında balık mevcudiyeti, pazar koşulları ve tüccarların geçim durumu

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Abstract: This study was conducted in a dry fish market (Saidpur City dry fish market) in northern Bangladesh from January 2023 to June 2023 to evaluate the marketing status, price variation of available dry fish species, and livelihood status of dry fish traders. A mixed-methods approach was used in this research, utilizing both qualitative interviews and quantitative surveys. Findings revealed that there were 17 different types of dry fish along with 5 types of semi-fermented and salted fish products in the market. The average price of dry fish in the market ranged from 3.67 to 4.59 USD/kg. Surma was the most expensive fish available in the Saidpur city dry fish market (4.59-9.17 USD/kg) while Baspata was the cheapest. The livelihood status of dry fish traders was found to be closely linked to market conditions. Their income levels varied significantly depending on the location and size of the market. It was found that 48% of the traders earned 1.83 to 4.59 USD/day, while 44% of retailers earned 4.59 to 9.17 USD per day. Only 8% of the traders had a daily income above 9.17 USD. In the present study, it was observed that 62% of retailers did not take any loans, while others borrowed from banks and non-governmental organizations (NGOs). About 58.33% of retailers did not have any alternative source of income and more than 50% of dry fish traders could not pass the primary level of education. This study identified both opportunities and challenges for the dry fish market. The major constraints faced by dry fish traders were a lack of credit facilities followed by high transportation costs and inadequate storage facilities.

Keywords: Dry fish, fish price, marketing channel, economic condition

INTRODUCTION

Fish is a significant provider of animal protein and necessary micronutrients for human health. Asian people typically consume fish as their main source of animal protein (Jahan et al., 2021; Phillips et al., 2015). Although fresh fish is preferred by most Bangladeshis, chilled and dry fish are also very popular in urban and suburban areas. The export of dry fish has increased in the country to 3,301 crore BDT (302.84 million USD) in 2021-22 statistical year from 233 crore BDT (21.38 million USD) in 1997-98 (1 USD equal to 109 BDT during the study period). The revenue has increased from 3.11 million to 844.40 million BDT (Bangladeshi currency) during that period (BBS, 2023). Fresh fish makes up around 70% of the fish sold commercially, dry fish makes up 25%, and the other traditional fish processing methods include fermented and frozen products (Faruque et al., 2012). The dried fish industry offers employment to a large number of individuals, with a significant portion being women (Belton et al., 2022).

Fish drying is a vital traditional preservation technique that involves removing water from the food to prevent microbial growth (Lithi et al., 2020). Drying has some advantages over other processing techniques like freezing, chilling, and smoking, such as lower production cost and smaller storage space (Bharda et al., 2017). In all of Bangladesh's coastal regions, marine fish is frequently dried, and there is a significant market demand for these dry fish on both the domestic and global markets. In Bangladesh, fish drying typically begins in October and lasts until March. The study of Nowsad (2005) found that in certain coastal areas, the season starts in early September and might extend until May. It is available for sale in international markets like Singapore, Hong Kong, Malaysia, United Kingdom, United States of America, United Arab Emirates, and other countries (Al Mehedi et al., 2020).

Saidpur is an upazilla in Nilphamari district of Bangladesh, where a well-known dry-fish marketplace was founded in 1983. The dry fish businesses are operational from February to September. The majority of fish are caught in the Bay of Bengal, except the Banded Snakehead (*Channa striata*) found in Chalan Beel in Pabna, Natore, and Bogura districts. Dry fish meets the protein demand of the people who live in Bangladesh's North Bengal areas. It provides 65-70% protein,

15-20% fat, omega-3 and omega-6 fatty acids, and other nutrients (Majumdar et al., 2023). Additionally, marine dry fish are rich in various minerals and vitamins. However, to destroy the microorganisms, in the conventional system of fish drying, the producers of dry fish use a variety of chemicals or pesticides, including Dichlorodiphenyltrichloroethane (DDT), Sobicron, Selcron, Setara, Nogos, Rocket, and Sumithion, which are harmful to human health (Islam and Kabir, 2019).

Fish are regarded as "white meat", which is advantageous for human health. Fish drying is an age-old preservation procedure that lowers the moisture content of fish, requiring lower storage temperatures than fresh fish. Bangladeshis, particularly in coastal, central, and northeastern districts, favor dried fish (Nowsad, 2007; Mamun-ur-Rashid et al., 2023). Most dry fish available in the dry fish markets in Saidpur City are marine species, with only a small number being freshwater fish (Islam and Kabir, 2019). The freshwater fish supply has declined due to urbanization and pollution. The fisheries industry is attempting to cope with this loss through the induced breeding of fish. However, a market study in Saidpur city revealed that the demand for dried and processed fish species is high in the domestic and international markets, but no significant research has been made to look into the state of the dry fish market in this area. This study was aimed to assess the current status of the dry fish market, availability of dry fish, sources, prices, storage, marketing channels, and restrictions in the retail dried, as well as to evaluate the hygienic condition and quality of dry fish in the dry fish market of Saidpur, Bangladesh.

MATERIALS AND METHODS

A survey was conducted to collect data from various stakeholders of a dry-fish market, such as traders, processors, intermediaries, and consumers. The period of the study was from January to June 2023. Before the survey, participants' permission was considered, and all respondents were informed about the principal goal and possible benefits of the research. All participants' willingness for this study and anonymity have been assured as well as confidentiality of each interview was strictly maintained. The formal ethical agreement for this study was received from the ethical committee of the Department of Aquatic Environment and Resource Management; Faculty of Fisheries, Aquaculture and Marine Science; Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Figure 1 shows an overview of the methodology.

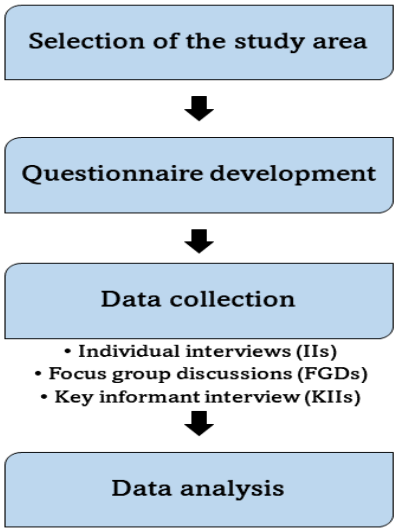

Figure 1. Flow diagram showing the methodology used for data collection

Selection of the study area

The study area was the Saidpur city dry fish market of Nilphamari District, Rangpur Division, Bangladesh. It is the commercial hub for the surrounding districts having a population of 312,988 (BBS, 2022). The study location was between 25°46' N and 88°53' E (Figure 2). It's a dry fish wholesale market situated near the Saidpur bus terminal. The dry fish shops are located on both sides of the road. This market is the second largest dry fish market in Bangladesh after Chattogram. It is also famous and popular in the northern part of Bangladesh; prices in the market are also reasonable with the quality of fish. Various types of dry fish from the local rivers and the sea are available here.

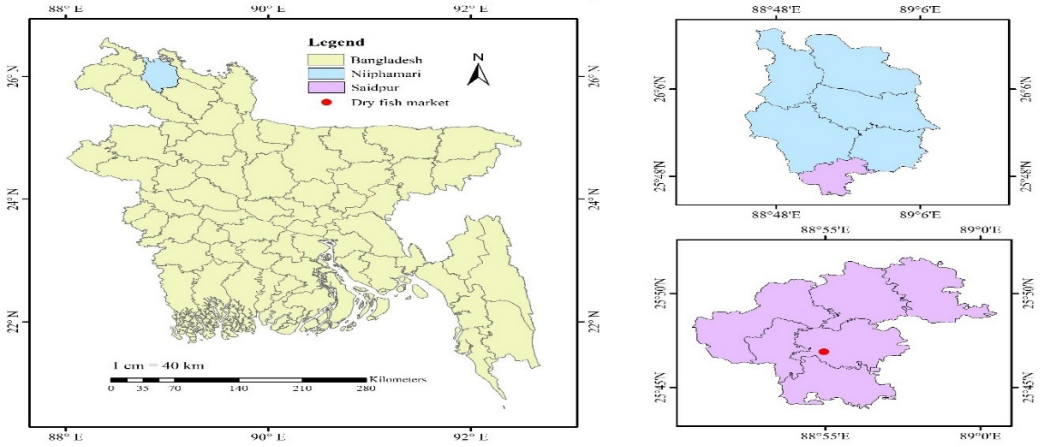

Figure 2. Map indicating the location of the study area (25°46' N and 88°53' E)

Questionnaire development

A semi-structured questionnaire was prepared to collect data. It was used to collect data for a part of the study area in order to test feasibility and effectiveness. The questionnaire was pretested on the ground and subsequently moderated based on the outcomes.

Data collection

Data were collected using participatory rural appraisal (PRA) tools i.e., individual interviews, focus group discussions, and key informant interviews (Table 1). The application of PRA tools aided a participatory and inclusive approach, engaging local stakeholders to opine on their social demographics and livelihood status.

Table 1. A summary of the empirical data collection procedure

Tools	Participants	Total participants	Research objectives
Individual interviews (IIs)	Dry fish traders, processors, market intermediaries, fishers involved in fish drying practices, consumers	40 (Male-30, Female-10)	Socio-demographic factors, fish availability, education, occupation, housing condition, income, savings, credit access, etc.
Focus group discussions (FGDs)	Young and elderly fish traders, community leaders, consumers	20	Semi-structured data gathering method that allows respondents to discuss critical issues
Key informant interview (KIIs)	Experienced traders, learned persons, researchers, government officials, NGO workers	12	Cross-checked and validated the collected data

In this study, a total of 72 individuals participated in different PRA tools. Individual interviews were conducted with 40 respondents one-on-one to collect qualitative and quantitative information. Before the interviews, the respondents were informed about the purpose and nature of this study, and their consent was obtained. Each interview was conducted for 30–40 minutes. In addition, two (02) focus group discussions, each with ten (10) participants, were conducted with various stakeholder groups to foster interaction and generate new knowledge. Each group consisted of 10 people and had a checklist, with each session lasting for 70–80 minutes. Furthermore, 12 key informants were interviewed face to face. The specific goal of such discussions was to gather data on fish drying and marketing processes, pricing, and value addition for dry fish at various levels, the supply chain, transportation, and lastly the credit system in the dry fish industry. It is worth mentioning that consistency and data reliability were ensured through FGDs and KIIs as these facilitated cross-checking of the gathered information.

Data analysis

Following data collection, data were modified for analysis. Data were collected in local units and converted into standard units for accurate analysis. The acquired data were properly summarized and tabulated in a sheet which was then transferred to the computer. The accuracy of the data was verified by comparing the original data sheets to computer spreadsheets. R and RStudio were used to process, analyze, and visualize data.

RESULTS

Dry fish sellers and consumers

In Saidpur city dry fish market, there were about 70 permanent dry fish shops with 50 owners. Some owners possess several shops and some makeshift dry fish sellers sell their products on vans and using var (a bamboo stick carrying two baskets).

It was found that 66.67% of consumers were low-income people (income $1,025 or less/year) while only 8.33% high-income people (income $12,476 or more/year) consumed dry (Figure 3).

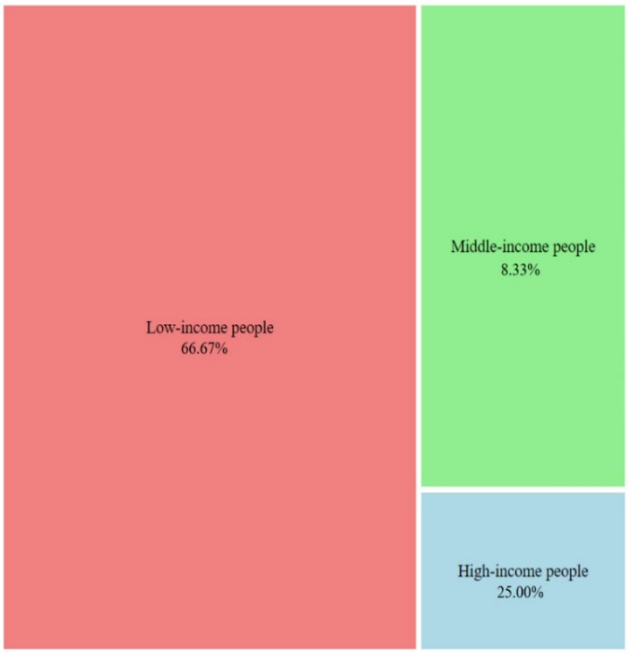

Figure 3. Distribution (%) of dry fish among different level of consumers

Availability of dry fish

In this study, we observed 18 species of dry fish and 5 types of semi-fermented and salted fish products in the Saidpur city dry fish market. Among the fish species found, 14 were freshwater, and only 4 were marine; however, in terms of price, Surma and Churi, two marine species, were the

highest. The price range varied from 1.83 to 9.71 USD/Kg. The most common dry fish species were Loitta, Churi, Holufa, Bata, Icha, Chewa, and Kachki. However, the survey recorded that the most popular and highest-selling items in the market were Loitta, Chewa, Holufa, Bata, and Churi.

Figure 4 displays the available dry fish species and their prices, while Table 2 provides data on the pricing of various semi-fermented and salted fish products. In the case of semi-fermented and salted fish products Kata Ilish and Nona Ilish were sold at the highest price (Table 2).

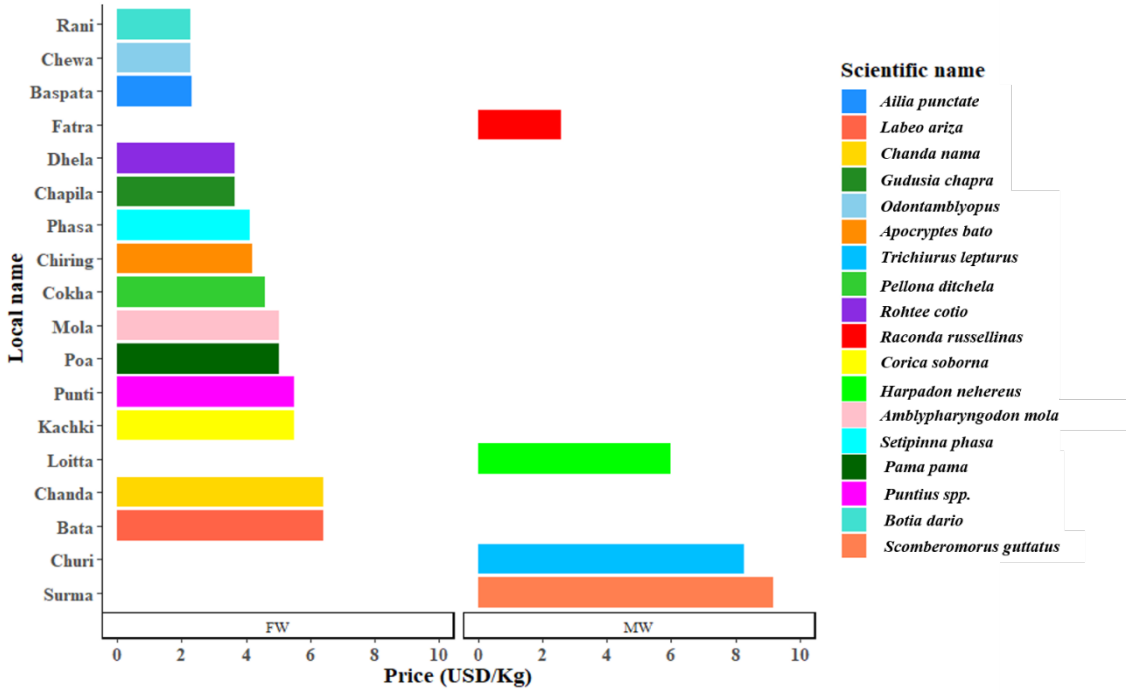

Figure 4. Available fish species price (USD/kg) in the study area

Table 2. Prices for semi-fermented and salted fish products

Local Name	Habitat	Scientific Name	Price (USD/kg)
Chingri	Marine water	*Penaeus monodon*	1.83-6.42
Punti shidal		*Puntius sp.*	2.75-5.96
Kata hilsha	Freshwater	*Hilsha ilisha*	4.58-8.25
Nona hilsha		*Tenualosa ilisha*	4.58-7.33
Phasa shidal		*Setipinna phasa*	1.83-4.58

Sources and supply of dry fish to Saidpur city market

The dry fish merchants from Khulna, Sylhet, Chittagong, Mymensingh, and Chalan Beel region (the north-west of Bangladesh) brought their fish to the Saidpur city dry fish wholesale market of Nilphamari district. The Saidpur city wholesale market was adjacent to two dry fish retail markets with 30 stores each. In the study region, there were a lot of mobile vendors who sold dry fish by physically carrying it on their bikes, vans, or rickshaws (Figure 5).

Dry fish sourced primarily from the Saidpur city wholesale market were supplied to the districts of Nilphamari, Thakurgaon, Dinajpur, and Panchagar. Thakurgaon district was the highest (35%) receiver of dry fish from the Saidpur city wholesale market. On the contrary, Dinajpur district received the lowest supply of dry fish (15%).

Marketing season

In this survey, the peak season for dry fish sales was the rainy season (June to October), followed by winter (October to March) and summer (March to June) (Figure 6).

Marketing channel of dry fish

According to our study, there was no particular marketing chain in Bangladesh for these fishery products, and the length of the channel varied depending on the location and time of year. Wholesalers and retailers acquired dry fish through a variety of intermediaries and the number of intermediaries was in between 2 to 6 during the survey. Figure 7 depicts the dry fish marketing channel in the Saidpur City dry fish market. It was noted that the retailers occasionally obtained the dry fish directly from the processors to increase their profit. It was found that longer marketing channels incurred higher costs. Likewise, the longest marketing channel was found for marine fish Surma and Churi.

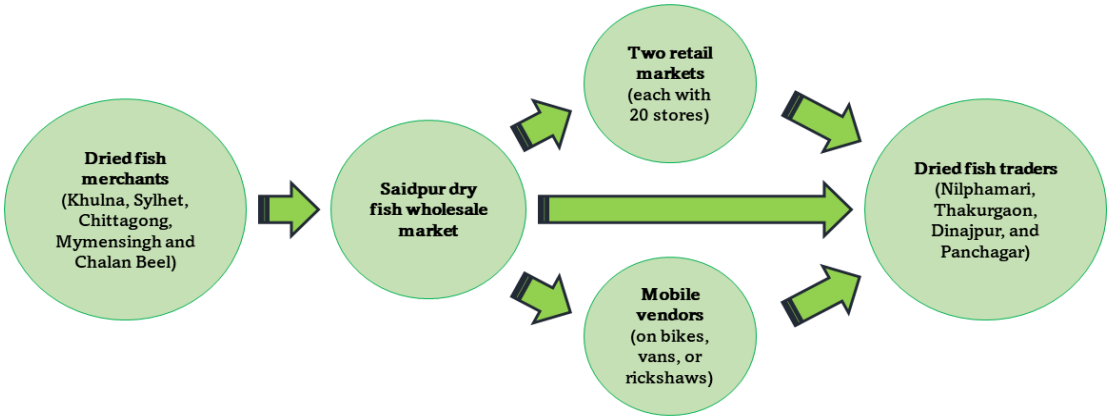

Figure 5. Sources and supply procedure of dry fish to/from Saidpur City dry fish market

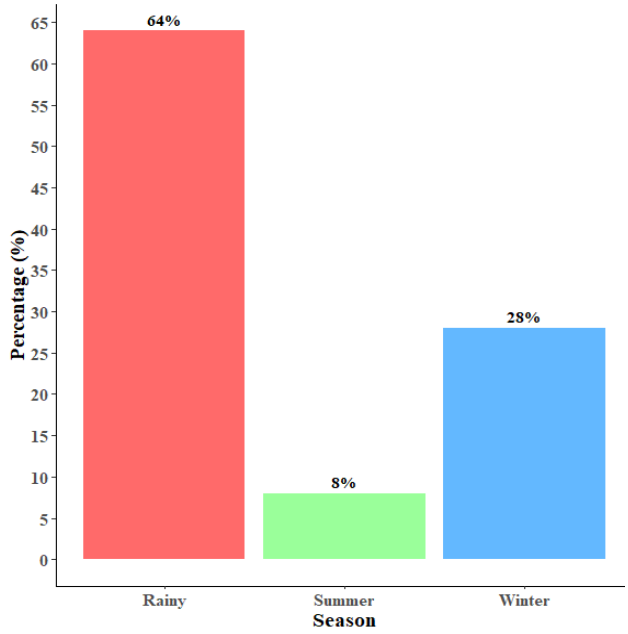

Figure 6. Peak seasons for the marketing of dry fish

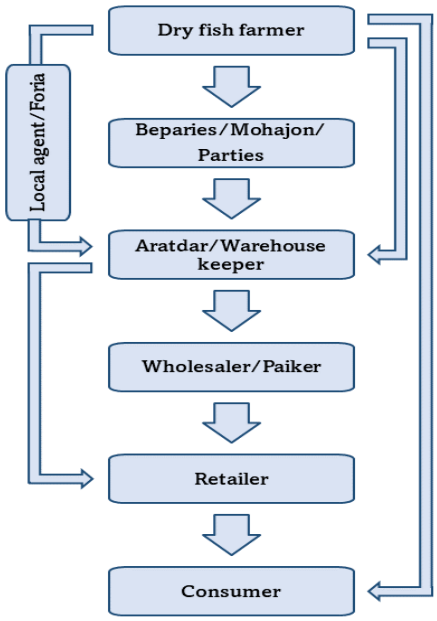

Figure 7. Dry fish marketing channel in Saidpur city dry fish market

Transport and storage

The research revealed that dry fish was transported via trucks, pickup trucks, or buses. The mode of transportation depends on the location of the market. Transportation of dry fish could take from 2 to 10 hours depending on the place of purchase. The storage period of dry fish might vary from a week to two months according to the sales. Plastic bags, jute bags, and wooden baskets were just a few of the many types of bags and baskets used for storage. Products made with Hilsha were stored in plastic buckets and bowls. Shidal of Punti and Faisa were preserved in an earthen vat. The dry fish was kept without refrigeration. It was notable that only 18 shops had storehouses during the survey of 70 permanent shops. No incidents of insecticide application for dry fish during storage were reported in the survey. The producers only used mustard oil to preserve products made from Hilsha, such as Nona Hilsha and Kata Hilsha. However, some respondents stated that fly infestation on dry fish resulted in financial loss. It was evident that the infested dry fish was sold at a discount price to the manufacturer of the fish meal. Moreover, 37.50% of respondents stated that they used preservatives to stop insect infestation, sepsis, and to make the color brighter.

Socio-economic condition of dry fish traders

Table 3 provides a socio-economic overview of dry fish retailers. The dry fish traders are from various age groups. However, 50% of them belong to the age group of 21-35. 33.33% of individuals had 21 to 30 years of experience, and 29.17% had 5-10 years of experience (Table 3).

Three-quarters of the participants had primary or high school education. The current study found that 58.33% of interviewees had no alternative source of income while rest had alternative means of revenue such as grocery shop (8.33%), crop farming (16.67%), and livestock rearing (4.17%) (Figure 8).

Table 3: Socio-economic condition of dry fish retailer

Parameters	Categories	Number of respondents	Percentage (%)
Age group (year)	<20	3	4.17
	21-35	36	50.00
	35-50	27	37.50
	>50	6	8.33
Education level	Illiterate	9	12.50
	Sign only	9	12.50
	Primary	30	41.67
	Secondary	24	33.33
Experience of business (year)	<5	6	8.33
	5-10	21	29.17
	11-20	18	25.00
	21-30	24	33.33
	>30	3	4.17
Sources of alternative income	Yes	30	41.67
	No	42	58.33
Daily average sell (kg)	1-5	33	45.83
	5-10	21	29.17
	10-20	12	16.67
	>20	6	8.33
Daily average income (USD)	1.83-4.58	36	50.00
	4.58-9.17	30	41.67
	>9.17	6	8.33
Housing structure	Katcha (strponents)	2	2.78
	Tin-shed	48	66.67
	Half cemented building	20	27.77
	Cemented building	2	2.78

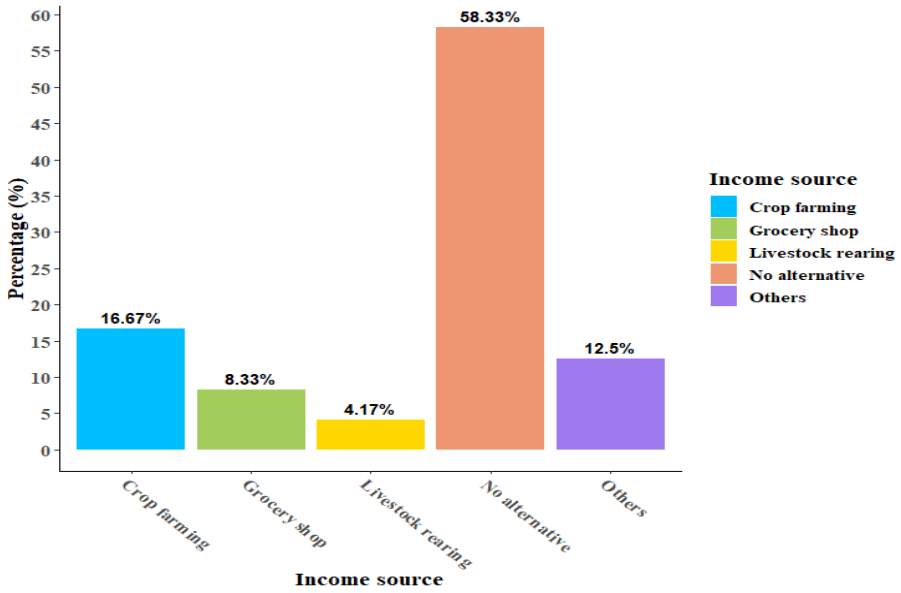

Figure 8. Different income source of fish traders

According to the survey, 45.83% of retailers sold 1-5 kg of dry fish per day, while 29.17% sold 5-10 kg per day. Half of the traders earned 1.83 to 4.58 USD/day while 41.67% of farmers earned up to 9.17 USD. Only 8.33% of farmers earned more than 9.17 USD (Table 3).

Figure 9 depicted that 37.50% of the dry fish traders consulted the village doctor locally known as Kobiraj for health issues, while just 12.50% have access to doctors having a Bachelor of Medicine and Bachelor of Surgery (MBBS). According to the current survey, the majority of respondents (83.33%) used their own tube well for drinking water, while 16.67% of retailers utilized a neighbor's or a public tube well.

In our study, it was observed that the majority of respondents (62.22%) financed their business with their own capital, whereas the remaining retailers took loans from banks and local NGOs (Table 4).

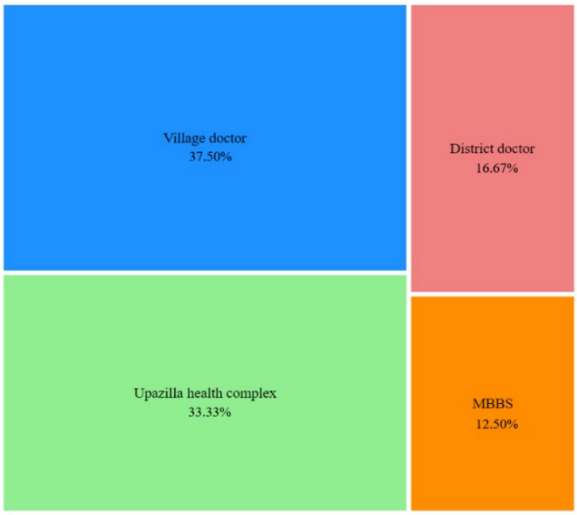

Figure 9. Various types of health facilities for retailers in the study area

Table 4. Credit facilities of the retailers in the study area

Credit facilities	Percent of retailers (%)
Not taking loan	62.22
Bank	5.00
NGOs	32.78

Major constraints of the dry fish market

The dry fish market in Saidpur city had a number of challenges including capital shortage, high transportation costs, insufficient storage space, and unhygienic market conditions. Besides, some interviewees mentioned other constraints like interference of local influential persons and availability of alternate protein sources like meat or fresh fish (Figure 10). In the present study, 33.33% of respondents think they could not smoothly run the business due to the shortage of capital. In addition, one-quarter of respondents expressed that higher transportation costs have taken a toll on their business. Furthermore, 16.67% of respondents found inadequate storage facilities a hurdle for their business.

In addition, quality control and hygiene standards are a significant challenge. Ensuring that dry fish products meet safety and quality standards is essential, but it can be difficult to maintain these standards throughout the production and distribution chain. 12.50% of the respondents perceived that dry fish is unhygienic. Finally, competition from alternative protein sources and imported products can influence the dry fish market. Affordable and readily available substitutes can challenge the market's growth and profitability. Addressing these constraints is crucial for the sustainable development of the dry fish industry.

DISCUSSION

In the study area, there were a total of 70 permanent shops and several temporary shops. Kleih et al. (2003) found that there were 200 wholesalers in the Asadganj dry fish market, Chattogram which is the largest in Bangladesh, and people in that region historically like dry fish. It is believed that low-income people consume more dry fish than rich people in society. The probable reason is that it requires a small amount for a meal and there are no issues with storage. On the other hand, comparatively high-income people are not inclined to take dry fish due to the popular belief that during the storage of dry fish, different chemicals or pesticides are used. A Similar trend was observed in research conducted by Islam et al. (2020). The study revealed that 36% of customers worked in business and 27% worked in low-wage jobs without a bachelor's degree, whereas 11% of consumers were middle to upper-class job holders with a bachelor's degree.

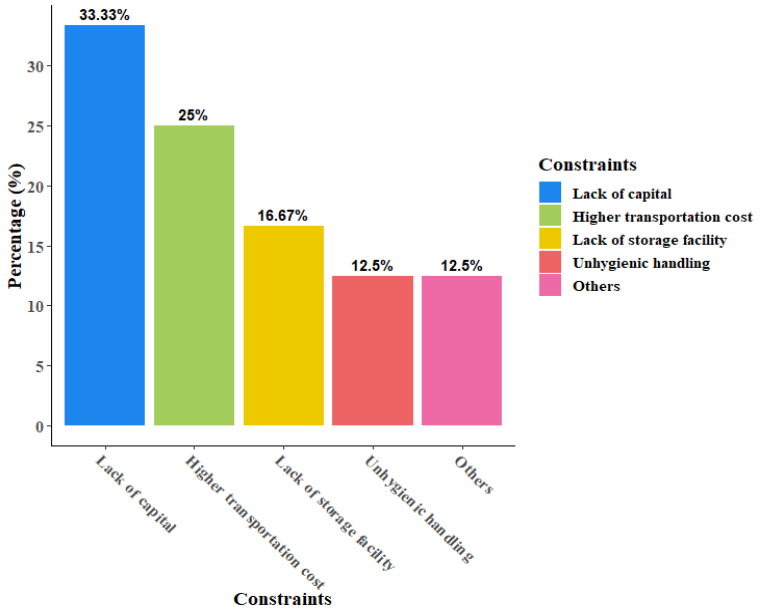

Figure 10. Some major constraints facing in the dry fish market

A total of 23 dry fish products, 18 different species and 5 types of semifermented products, were found in the study area. Of which only four types of dry fish were from marine sources because of the location of the market which is situated far from the sea. Haque et al. (2015) and Hasan et al. (2016) observed 35 (29 freshwater species) and 22 (all freshwater species) dry fish species in dry fish markets in Sylhet, Bangladesh, respectively. Flowra et al. (2010) reported 25 dry fish species in the different markets of Rajshahi and Thakurgoan. Species of a market can vary due to the source of fish and consumers' preferences. In this study, the price ranges varied from 1.83 to 9.71 USD/Kg. Hasan et al. (2016) found the price variation from 2.75-7.34 USD/kg in Sylhet, Bangladesh, and Monir et al. (2013) observed the ranges of price from 0.78 to 5.50 USD/kg. Although a bit of variation was noticed due to the time difference of conducting research, both studies support our findings. In Bangladesh, dry fish is produced commercially in significant amounts in Nazirartek, Choufaldandi, Khurushkul, Maheshkhali, and Teknaf of Cox's Bazar district (Alam, 2005; Hossain et al., 2015). It is also found in other districts namely Rajshahi, Thakurgaon, Patuakhali, Sundarbans, Nilphamari, Mymenshingh, and Sylhet (Al Mehedi et al., 2020). Sources of dry fish in a market depend on the distance of the market from that source and the communication system and associated cost. Dry fish from the Chalan beel region reached this market owing to the shortest distance and minimal cost.

The availability of dry fish and fresh fish in a particular region may impact the supply chain in that region. Thakurgaon district received more dry fish than other districts. This is because of lower dry fish production (0.1 metric ton) in Thakurgaon compared to other districts. On the other hand, Dinajpur acquired less as it had an available supply of fresh fish from its sources (DoF, 2022). As of today, no fish has been exported abroad from the region commercially which was observed in other fish markets in the country like Asadganj Dry Fish Market, Chittagong (Faruque et al., 2012). In the study, the peak season of dry fish trading was found from June to October and the lean season was observed from March to June which was slightly different from the findings of Ghorai et al. (2014) and Faruque et al. (2012), respectively. Ghorai et al. (2014) found peak season during October-January in Egra dry fish market, East India and Faruque et al. (2012) found November in a dry fish market in Chittagong, Bangladesh. However, Hossain et al. (2013) stated that dried marine fish is consumed all year long, whereas dry freshwater fish is more sporadic and more readily available in the winter. This study along with other research findings revealed that the market channel of dry is not fixed. In the study of Flowra et al. (2010) most of the retailers were found to buy dry fish from the aratdars of Feni and Chattogram and some from wholesalers of Chowmuhani, Noakhali in terms of necessity. Similar results are observed by other researchers (Aziz et al., 2019; Purkait et al., 2018). It is assumed that the length of the channel varied depending on the location and time of year. In this survey, it was found that different vehicles are used for transportation. Faruque et al. (2012) stated that traders transported products by boat/mechanical boat, vehicles, head loads/shoulder loads to the Asadganj fish market, Chattogram. According to Hall (1997), there might be high risks of rancidity during prolonged storage conditions due to the fatty nature of fresh fish. However, in the case of this study area, such a problem was not heard of as mostly lean fish were chosen for drying.

The socio-economic condition of dry fish retailers in Bangladesh might vary based on factors such as location, market dynamics, and government policies. From this current survey, it was assumed that dry fish retailers often come from lower-income backgrounds and rely on this business for their livelihood. In the current study, it was recorded that 87.50% of traders fall in the age range from 21-50 years old. An earlier study on the socioeconomic situation of dry fish retailers reported that the retailers' ages ranged greatly from 20 to over 55 years old (Nath et al., 2013). Age and years of experience impact the income of stakeholders as fish drying is an assiduous activity (Kaiya et al., 1987). Though only 41.67% of traders had alternative income sources they are engaged in various works. Ahmed et al. (2007) revealed diverse livelihoods in Kutubdia Island and Cox's Bazar which is similar to this study. Findings showed that approximately 51% rely on off-farm activities, notably fishing, 18% on non-farm work, 4% on livestock, 13% on small-scale aquaculture and farming, and 14% on off-farm wage labor. In the current study, it was observed that daily sales and income varied from 1 to >20 kg and 1.83 to > 9.17 USD. A study conducted in a dry fish market found that product sales varied from market to market and ranged between 4 and 10 kg per day (Hasan et al., 2016). A study found similar results where 48% of retailers earn 200-500 BDT (1.8-4.5 USD), 44% earn 500-1000 BDT (4.5-9.1 USD) and 8% earn more than 1000 BDT (9.1 USD) daily in a dry fish retail market in Noakhali (Saha et al., 2022). Moreover, the average income of retailers in seven dry fish markets was estimated as BDT 591.89/day/retailer (5.39 USD/day/retailer), whereas the average profit of retailers in seven markets was BDT 450.69/day/retailer (5.39 USD/day/retailer) (Aktar et al., 2013). These results also support our research findings.

The two-third (66.67%) traders lived in the tin shed house and almost one-third (27.77%) in half cemented buildings in the study area. Similar results are found in Barishal, Kuakata and Noakhali. Studies recorded a majority of dry fish producers used tin shed houses; 53.33% in Barisal (Kubra et al., 2020), 41.67% in Kuakata (Kubra et al., 2020) and 70% in Noakhali (Khatun et al., 2013; Leela et al., 2018). In terms of health facilities in the present study, 37.5% of people depend on village doctors locally known as kobiraj. Similarly, according to Ali and Haque (2011), 40% of fish farmers in the Mymensingh district rely on village doctors or kobiraj for health care. The drinking water scenario of the current study is fairly prevalent in Bangladesh (Ali and Haque, 2011). Most traders rely on their capital as dry fish trading does not require

a huge amount of money. However, one-third of the traders take loans from NGOs with high-interest rates. The findings were supported by Nayeem et al. (2010) and Ali and Haque (2011) for the fish farmers in the Mymensingh district.

The fish market of Bangladesh faces several constraints that impact its growth and sustainability, which may differ depending on the region and market characteristics (Nadia et al., 2022). The limitations identified in the study region were comparable to those found in other studies on both wholesale and retail markets for dried fish. These constraints included rapid spoilage of dried fish, low consumer demand, high transaction costs, poor management skills, limited access to credit facilities, and a lack of marketing infrastructure, transportation, and storage facilities (Monir et al., 2013; Shuchi et al., 2022). There is no denying the fact that the profitability of fish marketing has remained a persistent challenge for the industry (Adegeye and Dittoh, 1982). Rural farmers believe that a premium will be paid for fish in urban or pre-urban markets, but they are hampered by transportation issues (Akinneye et al., 2007) owing to limited market access and distribution barriers that pose hurdles. This is because dry fish is often produced in remote or coastal areas, which restricts its access to broader markets. Concerning hygiene, Reza et al. (2005) investigated traditional drying practices for marine fish in Bangladesh's coastal region. They found that processors commonly soak raw fish in insecticides like DDT and Nogos (Dichloroves) before drying, with concentrations ranging from 20-80 ppm. Traders should prioritize the production of safe dry fish to address consumer concerns about potential long-term risks to their families and others (Belton et al., 2022; Siddique, 2012). It has been stated that retailers confront different internal challenges when selling products in retail markets, such as interference by musclemen and local leaders (Amin et al., 2012), which is consistent with our findings.

CONCLUSION

For the people of Bangladesh, dry fish is a significant source of protein and minerals. Low-income people rely heavily on it because fresh fish is prohibitively expensive for them. The dry fish market also creates employment opportunities. Thus, the Saidpur region might have a great potential to be a key supplier of dry fish. However, the variety and the price of dry fish has fluctuated over the years due to various factors such as the time of year, supply and demand dynamics, and consumer preferences. Socio-economic factors, including the income levels and purchasing power of consumers, also play a crucial role in shaping the demand for dry fish. Most of the traders of the dry fish are significantly influenced by the changes in market conditions and consumer behavior. To thrive in this market, dry fish retailers need to adjust their strategies according to the socio-economic status and consumer preferences. Improving fish product hygiene and reducing marketing intermediaries can lower the price of product at the consumer level. Considering the challenges and opportunities, this region needs to be studied for further development of the dry fish industry. Additionally, it is recommended to study the interplay between market trends and socio-economic conditions, which would facilitate policymakers to make informed decisions to sustain the dry fish business and improve the livelihood status of the fish traders.

ACKNOWLEDGEMENTS

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AUTHORSHIP CONTRIBUTIONS

Md. Foysul Hossain: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, review & editing. Md. Mosiur Rahman: Data curation, Methodology, Formal analysis, Writing –original draft. Truong Dan Nguyen-Pham, Koushik Chakroborty and Bhaskar Chandra Majumdar: Methodology, Investigation, Writing – review & editing.

DECLARATION OF INTEREST:

Authors declare no conflicts of interest in the reported work.

ETHICS APPROVAL STATEMENT

Ethical approval for this study was obtained from The Ethical Committee, Department of Aquatic Environment and Resource Management, Faculty of Fisheries, Aquaculture and Marine Science, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh.

DATA AVAILABILITY

Data will be made available on request.

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

A checklist of algae from Afghanistan

Afganistan alg türleri kontrol listesi

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Abstract: This first comprehensive checklist of algae from freshwater and soil in Afghanistan is a significant milestone in understanding the country's biodiversity. It is the result of a collaborative effort by researchers from various institutions. It comprises 398 species belonging to 132 genera and five phyla of algae, with samples collected from 19 regions of Afghanistan. The *Nitzschia* and *Navicula genera* have the most significant number of species. The checklist also highlights the sensitivity and threatened status of certain species, such as *Achnanthidium gracillimum* (F. Meister) Lange-Bertalot, *Brachysira serians* (Brébisson) Round & D.G. Mann, *Diploneis ovalis* (Hilse) Cleve, *Eunotia praerupta* Ehrenberg, *Eucocconeis flexella* (Kützing) F. Meister. The currently accepted name of species, biological condition gradient of species, the status of species in the Red List of Germany, and trophic weight of some diatom species according to two diatom trophic indices were defined in the checklist. This study is a new start for this field of study and intends to provide the groundwork for further research, which will aid in the work of others interested in this topic.

Keywords: Biodiversity, diatoms, biological condition gradient, species

Öz: Afganistan'daki tatlı su ve topraklardan alınan alglerin ilk kapsamlı kontrol listesi, ülkenin biyolojik çeşitliliğini anlamamızda önemli bir dönüm noktasıdır. Çeşitli kurumlardan araştırmacıların verileri ile oluşturulan bu çalışma, Afganistan'ın 19 bölgesinden toplanan örneklerle 132 cinse ve beş bölüme ait 398 türü kapsamaktadır. *Nitzschia* ve *Navicula* cinsleri en fazla türe sahip olan cinslerdir. Liste ayrıca, *Achnanthidium gracillimum* (F. Meister) Lange-Bertalot, *Brachysira serians* (Brébisson) Round & D.G. Mann, *Diploneis ovalis* (Hilse) Cleve, *Eunotia praerupta* Ehrenberg, *Eucocconeis flexella* (Kützing) F.Meister gibi bazı türlerin hassasiyetini ve tehdit durumunu vurgulamaktadır. Kontrol listesinde türlerin güncel kabul edilen isimleri, biyolojik durum gradyanları, Almanya'nın Kırmızı Listesi'ndeki durumları ve iki diyatome trofik indeksine göre bazı diyatome türlerinin trofik ağırlıkları tanımlanmıştır. Bu çalışma, bu alandaki araştırmalar için yeni bir başlangıç olup, bu konuyla ilgilenen diğer araştırmacıların çalışmalarına temel sağlamayı amaçlamaktadır.

Anahtar kelimeler: Biyoçeşitlilik, diyatomeler, biyolojik durum derecesi, türler

INTRODUCTION

Algae are the most important primary producers in both freshwater and marine habitats. They play a significant role in regulating the ocean's silicon cycle and are known as the fastest-growing organisms; algae are crucial organisms that play important roles, ranging from freshwater to oceans, and are involved in various significant fields, from biocatalysts in space research and water quality assessments to sustainable development efforts. (Çelekli and Zariç, 2024a, 2024b; Yool and Tyrrell, 2003; Zariç and Çelekli, 2024). Environmental monitoring has become increasingly important under changing environmental conditions (Çelekli and Zariç, 2023a). Algae are valuable for taxonomists and ecologists in monitoring archaeological and present environmental conditions (Çelekli et al., 2023; Zariç et al., 2024). They are often utilized in water quality investigations because they are sensitive to environmental factors such as water acidification, eutrophication, and climate change; among algae, diatoms have also been utilized as helpful indicators to assess water quality (Çelekli and Zariç, 2023b; Van Dam et al., 1994) Smol and Stoermer, 2010; Schlüter et al., 2012; Çelekli et al., 2023). Diatom communities help evaluate how ecological conditions vary over time and between sites. These species are widely distributed throughout habitats on the Earth; they are trusted biological indicators that are used to analyze extensive environmental data (Rott et al., 1999; Della Bella et al., 2012; Delgado and Pardo, 2015; Çelekli et al., 2019).

A checklist can deliver a great deal of knowledge with little work. Until a specific date, checklists represent taxonomic knowledge found in the literature. The list of species names may not be based on accurate taxonomic information for species without recent taxonomic revisions, and downstream conclusions may be inaccurate. The only precise method to handle each species' nomenclature status is through taxonomic revisions (Dayrat, 2011). It is necessary to make a collective vision for taxonomy, systematics, and biodiversity to realize it by utilizing existing and upcoming resources. The connection between floras, checklists, and biodiversity studies is crucial for accessing up-to-date information. Collaborating with taxonomy societies can help establish a unified network of flora and fauna sites. Taxonomists should actively engage in global initiatives to interconnect and share data (Funk, 2006). Checklists play a vital role as they provide a systematic compilation of species from specific regions, offering valuable insights for biodiversity conservation, ecological research, and environmental assessment and monitoring. For these reasons,

numerous checklists (Singh et al., 2023; Bacci et al., 2024; Álvarez et al., 2023; Daniel et al., 2023) have been reported from various ecoregions.

There are several checklists available for Afghanistan's flora and fauna. For example, a thorough inventory of the plant species in the area is provided by the checklist of vascular plants (Breckle et al., 2013). Wagner et al. (2016) reported that a checklist of reptiles and amphibians records the diversity of these particular species. Additionally, research and inventory of big animals from Afghanistan's eastern woodlands provide light on the existence and range of critical mammalian species (Stevens et al., 2011). These checklists help study and preserve Afghanistan's biodiversity and are essential tools for academics and conservationists.

The first publication about the algae of Afghanistan was published in 19. century (Schaarschmidt, 1884). A taxonomic study of diatoms was published (Foged, 1959). Unfortunately, no significant research and articles on this subject have been published since then. As per the available data, algae are employed extensively in scientific research to examine the condition of several aquatic habitats. Unfortunately, Afghanistan has had several difficulties that have prevented published checklists for algae from reaching the nation for many years. This lack of data creates a big hole in the field. As a result, attempts are underway to create an exhaustive catalog of algae unique to Afghanistan. The primary aim of this investigation was to compile data on the algal species that have been documented in Afghanistan. Additionally, new taxonomies were created, and significant traits were identified. This study is a new start for this field of study and intends to provide the groundwork for further research, which will aid in the work of others interested in this topic. Through further study within the borders of Afghanistan, we are dedicated to adding to this checklist.

MATERIALS AND METHODS

Study of area

According to hydrological characteristics, Afghanistan has five major river basins, including the Kabul (Indus) River Basin, Amu-Darya River Basin, Northern River Basin, Hari Rud-Murghab River Basin, and Helmand River Basin (Hayat and Tayfur, 2023). Numerous algae species collected in the current checklist were obtained from stations in these river basins. Most species documented in the checklist have been reported from 19 locations in Afghanistan (Figure 1). Due to the lack of data on the coordinates of the sampling stations in the sources, it was not easy to define the exact location of the sampling stations. For this reason, the sampling stations are shown as approximate in Figure 1 from S1 to S19 (Table 1). There were several species whose sampling location was not clearly explained or named by the researcher, so a separate column was created in the checklist table to identify them.

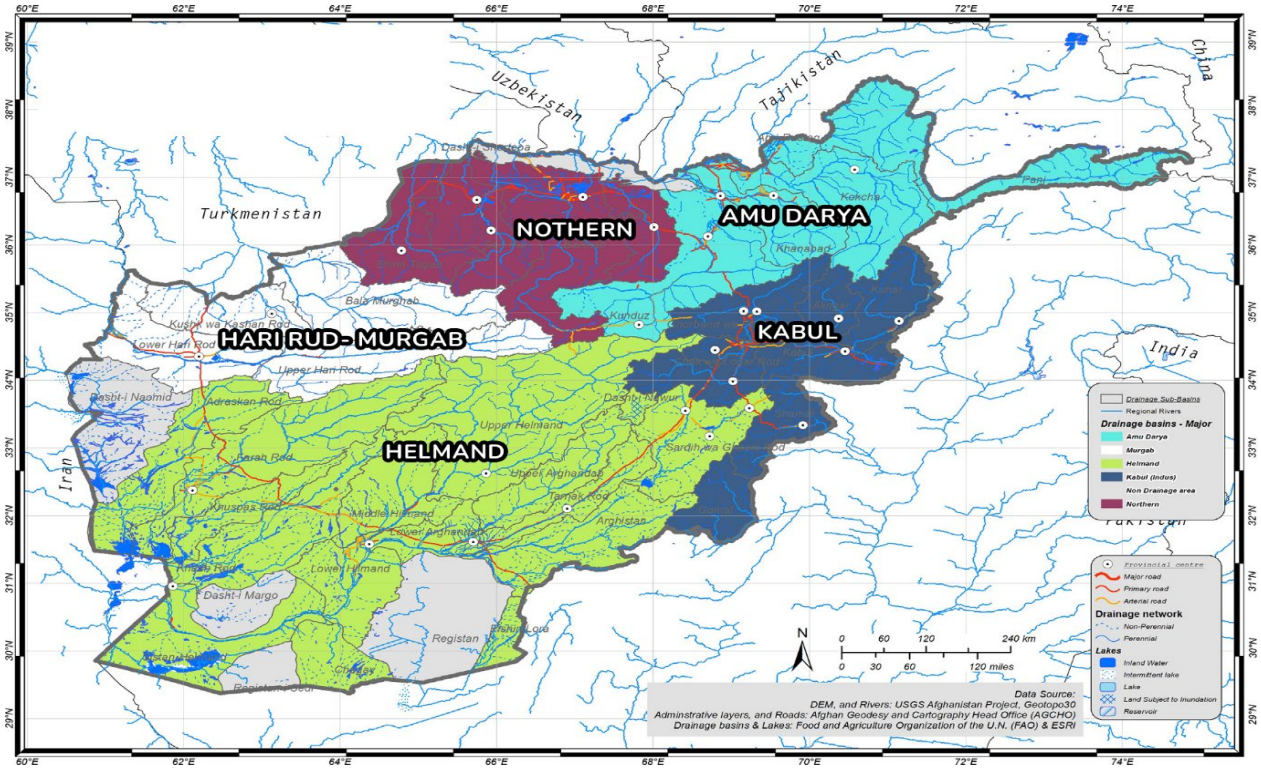

Figure 1. Map of Afghanistan River Basins: Hari-Rud River Basin, Helmand River Basin, Northern River Basin, Amu Darya River Basin, Kabul River Basin. The species documented in the checklist from different water bodies in Afghanistan (Ahlers et al., 2014)

Table 1. The full names of the sampling stations are shown in Figure 1, which are called S1 to S19

Code	Name of locations	Code	Name of locations
S1	Murghab-Maimana River	S11	Panjao small River
S2	Qala Nau-Murghab River	S12	Band-i Amir (Lake)
S3	Upper Hari Rud River Basin1	S13	Upper Helmand (Farakulum) River2
S4	Upper Hari Rud River Basin2	S14	Upper Helmand (Hauz-i-Mahiha) River3
S5	Shin Dand (Sabzewar) River	S15	Sar-i Chasma Stream1
S6	Dilaram (Khash Rud) River	S16	Sar-i Chasma Stream2
S7	Upper Helmand River1	S17	Andarab River
S8	Girishk River	S18	Panjshir River
S9	Lal-i-Sarjangel River	S19	Nuristan Stream
S10	Mokur Canal		

Extensive efforts were made to gather pertinent papers and information from many reliable sources to create a checklist of algae that have been identified and studied in Afghanistan up to this point. The most recent and correct information on the recognized names of species was checked according to the currently accepted taxonomic names in the Algaebase (2024). Furthermore, the Diatoms of North America (2024) and RoteListe (2024) websites were utilized as additional resources to define the Biological Condition Gradient (BCG) and determine the threatened status of species (Red List). These websites offered valuable insights into the ecological status and conservation concerns associated with species. The checklist is attached in Appendix 1.

Assessment of species sensitivity and threat status

We employed specific methods and criteria to examine species sensitivity and identify highly threatened species. The Biological Condition Gradient (BCG) framework evaluated species sensitivity based on their ecological requirements and responses to environmental stressors. The criteria included habitat specificity, pollution tolerance, and reproductive capacity. The threatened status of species was determined using the Red List categories provided by the RoteListe (2024) website. This approach allowed us to systematically classify species into different threat levels, ranging from least concern to critically endangered. Detailed assessments and justifications for each species' sensitivity and threat status are documented in the checklist.

RESULTS

The checklist included 398 algal species from 132 genera and five phyla (Appendix 1). Heterokontophyta had the highest species (351 sp), followed by Charophyta (18 sp), Chlorophyta (17 sp), Cyanobacteria (9 sp), and Ochrophyta (3 sp). Their percentages are given in Figure 2. The highest number of species is related to the *Nitzschia* and *Navicula* genera.

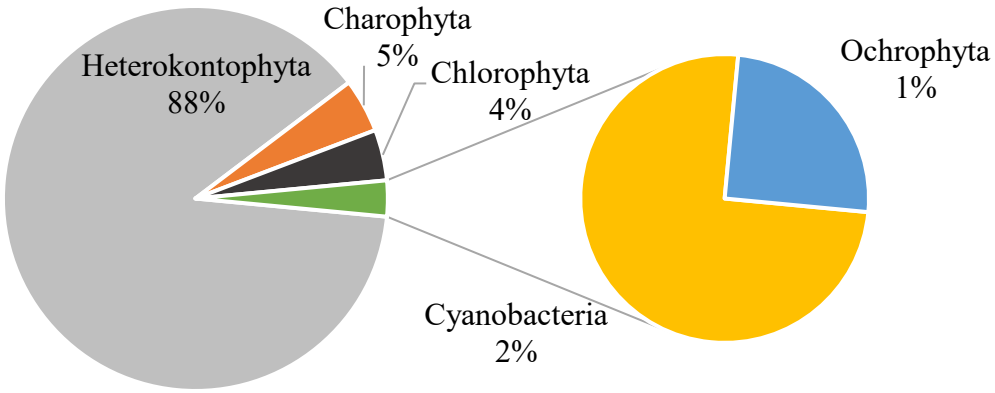

Figure 2. Percentages of phyla in the checklist

DISCUSSION

The currently accepted species names were checked according to the Algaebase (2024), documented in the checklist (Appendix 1) due to the possibility of changing some species' scientific and old names.

Some diatom species were commonly found in Afghanistan, like *Achnanthidium minutissimum, Caloneis leptosome, Cymbella neoleptoceros, Diatomella balfouriana, Encyonopsis microcephala, Mastogloia smithii, Muelleria gibbula, Navicula ramosissima,* and *Ulnaria ulna*. Some of these species have a widespread distribution and were reported from different ecoregions as dominant taxa. Intense Ulnari ulna was reported as the dominant species from the Patagonian River in Argentina (Espinosa et al., 2020). Aras River in Northwestern Iran (Parikhani et al., 2023), and also *Achnanthidium minutissimum* was defined as the dominant species in the Sava River (Zelnik and Sušin, 2020) and Kordan River in Iran (Adl et al., 2020).

A few diatom species, such as *Denticula thermalis, Pinnularia kneuckeri*, and *Stauroneis agrestis*, are scarce. *Achnanthidium minutissimum, Brachysira serians, Cymbella affinis, Diploneis ovalis, Eucocconeis flexella, Eunotia praerupta, Euastrum spinulosum, Psammothidium ventrale* are in highly threatened and *Cymbella helvetica, Encyonema perpusillum, Closterium cornu, Cosmarium contractum, Cosmarium pyramidatum, Cosmarium undulatum, Desmidium quadratum* are in threatened in the checklist (for more see Appendix 1). Unfortunately, *Cymbella latens,* with the currently accepted name of *Encyonema latens* (Krasske) D.G. Mann reported by Foged (1959) from the country, has been extinct or lost (RoteListe, 2024).

A further feature of this checklist is the availability of BCG of most of the species included in the checklist, which were discovered and included in the checklist from reliable sources. The Diatoms of North America (2024) website and the paper of Hausmann et al. (2016) were used extensively to find the BCG of diatoms species. Many of species in the checklist such as *Tabellaria fenestrate*, *Sellaphora bacillum*, *Reimeria sinuata*, *Meridion circulare*, *Hannaea arcus*, *Grunowia sinuate*, *Genkalia digitulus*, *Fragilariforma virescens*, *Eunotia rhomboide*, *Epithemia turgida*, *Denticula tenuis*, and *Cymbella aspera* are in level 2 of BCG (BCG = 2). This means that their environments were in natural status with minimum changes. Conversely, there are several species, for example, *Bacillaria paxillifera*, *Craticula accomoda*, *Cyclotella comata*, *Gyrosigma attenuatum*, *Halamphora veneta*, *Hippodonta hungarica*, *Navicula cincta*, *Navicula peregrina*, *Navicula tripunctata*, *Nitzschia amphibia*, *Nitzschia communis*, *Nitzschia microcephala*, *Nitzschia palea*, *Surirella ovalis*, *Tryblionella hungarica* were defined in level five of BCG (BCG = 5). This matter shows that some of the taxa in the checklist had lived in ecosystems with significant changes (Hausmann et al., 2016; Gerritsen et al., 2017; Paul et al., 2020; Diatoms of North America, 2024).

Endemic species such as; *Cymbella farakulumensis*, *Cymbella helmandensis*, *Cymbella panjaoensis*, *Cymbella sabzewarensis*, *Gomphonema farakulumensis*, *Navicula anderabensis*, *Navicula chasmaensis*, *Navicula farakulumensis*, *Navicula helmandensis*, and *Nitzschia anderabensis* were documented in the checklist (Foged, 1959). These species need to more investigation.

Trophic conditions are among the most crucial factors influencing the freshwater diatom habitats in rivers and lakes (Besse-Lototskaya et al., 2011). TI and TIT have been widely used in recent decades to evaluate running water ecosystems and surface water quality. For this reason, we have included the TI and TIT trophic weight of diatom species that were available in the checklist (Rott et al., 1999; Çelekli et al., 2019). In the checklist, there are many pollution-sensitive species, such as *Achnanthes coarctata*, *Achnanthidium minutissimum*, *Cymbella affinis*, and *Eunotia parallela,* and pollution-tolerant species, such as *Nitzschia paleacea*, *Nitzschia palea*, *Nitzschia pamirensis*, *Nitzschia nana*, and *Gomphonema parvulum* according to the trophic weight of diatom species in TI-Trophic Index (Rott et al., 1999) and TIT-Trophic Index Turkey (Çelekli et al., 2019).

As a comprehensive study for the first time, forty specimens of diatoms from the territory of Afghanistan (fresh and slightly saline water) were collected by the third Danish Central Asiatic Expedition in 1948-1949. Diatoms in the samples have been investigated. It has been attempted to determine every sample's pH and halation spectra to evaluate the locales' ecological status. All diatom species discovered in the material were listed, along with information about how frequently they occur in the samples and their most notable ecological relationships. Information including diagnoses of 17. nov. spec. 13 plates with 201 figure drawings from the Afghan material of diatoms were collected, and the result was published as a helpful book titled Diatoms from Afghanistan (Foged, 1959). Apart from this study, a comprehensive study in this field has not been published in the country. This book was a beneficial and contributing source for us to prepare the current checklist.

Although the number of species covered in this checklist is limited owing to a lack of resources, it includes species ultimately confirmed and recognized in the country. Most of these species have been reported from streams and rivers, but some species have been sampled from soil habitats. In the checklist, a column is titled the species' habitat, and the soil habitat is marked with an asterisk (Schaarschmidt, 1884; Foged, 1959; Rahmatzai et al., 2016).

In this study, we utilized autecological parameters derived from predominantly European studies. It is important to note that the ecological characteristics of these taxa may differ in Afghan ecosystems, and caution should be exercised when interpreting these parameters.

CONCLUSION

Owing to the myriad challenges Afghanistan has faced over recent decades, there has been a significant lack of

scientific research on ecological studies, species distribution, and detailed taxonomy. Consequently, the country has seen very limited studies focused on algae. There has not been a published checklist of diatom and algae species in the nation in recent decades. The current checklist includes 398 species of diatoms and algae from 132 different genera and five phyla collected from reliable sources. Most of these species were reported from 19 stations in Afghanistan. The currently accepted name of species, BCG of species, the status of species in the Red List of Germany, and trophic weight of some diatom species according to TIT and TI were defined in the Checklist. Some species in the checklist, such as *Pantocsekiella kuetzingiana*, *Pinnularia appendiculata*, *Planothidium lanceolatum*, *Surirella ovalis*, and *Cosmarium granatum*, are not threatened. Eight species (*Caloneis leptosoma*, *Cymbopleura similis*, *Diatomella balfouriana*, *Eunotia rhomboidei*, *Eunotia tenella*, *Fallacia vitrea*, *Muelleria gibbula*, and *Planothidium hauckianum*) are under threat of unknown extent according to the Red List of Germany in the checklist. This study not only fills a significant gap in Afghanistan's existing ecological and taxonomical data but also underscores the broader implications for biodiversity conservation and management. The checklist is critical for future researchers and conservationists aiming to protect and preserve Afghanistan's unique aquatic ecosystems. Future research should prioritize comprehensive surveys and advanced taxonomic studies to further document and understand Afghanistan's biodiversity of diatoms and algae. By expanding the scope of this research, we can better inform conservation strategies and contribute to global efforts in biodiversity preservation. This study marks a new beginning for this field of study and aims to lay the framework for future research, which will benefit the work of others interested in this topic. We are committed to expanding this checklist with additional research within Afghanistan's boundaries. Ultimately, the continuation and expansion of this research will enhance our understanding of Afghanistan's ecological richness and support global biodiversity records and conservation initiatives.

AUTHOR CONTRIBUTION STATEMENT

Abuzer Çelekli and Mostafa Mohammadi designed the overall work.

ETHICAL APPROVAL

There is no need for ethical approval for this study.

FUNDING STATEMENT

The authors do not declare any funds.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data used in this study are available from the corresponding author upon reasonable request.

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Appendix 1. The checklist of algae from Afghanistan. Red list (RL), Extinct or Lost (0), Threatened with Extinction (1), Highly Threatened (2), Threatened (3), Threat of Unknown Extent (G), Extremely Rare (R), Near Threatened (V), Not Threatened (*), Data Deficient (D), Not established (-), (RoteListe, 2024). BCG (biological condition gradient); BCG scores means: 1. Native or natural condition - 2. Minimal loss of species; some density changes may occur - 3. Some replacement of sensitive-rare species; functions fully maintained -4. Some sensitive species maintained but notable replacement by more-tolerant taxa; altered distributions; functions largely maintained - 5. Tolerant species show increasing dominance; sensitive species are rare; functions altered - 6. Severe alteration of structure and function.

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Achnanthes coarctata*	*Achnanthes coarctata* (Brébisson ex W.Smith) Grunow															+				+		D	–
	Achnanthes okamurae	*Achnanthes okamurae* Skvortzov										+											–	–
	Achnanthes pseudolinearis	*Achnanthes pseudolinearis* Hustedt																				+	–	–
	Achnanthes affinis	*Achnanthidium affine* (Grunow) Czarnecki																				+	*	–
	Achnanthes linearis	*Achnanthidium lineare* W.Smith																				+	G	–
	Achnanthes microcephala	*Achnanthidium minutissimum* (Kützing) Czarnecki	+			+							+	+		+	+		+	+	+		2	3
	Achnanthes pyrenaica	*Achnanthidium pyrenaicum* (Hustedt) H.Kobayasi																		+			*	3
	Navicula aquaeductae	*Adlafia aquaeductae* (Krasske) Lange-Bertalot																				+	R	–
	Navicula bryophila	*Adlafia bryophila* (J.B.Petersen) Lange-Bertalot																				+	*	–
	Amphipleura pellucida	*Amphipleura pellucida* (Kützing) Kützing															+						*	3
	Amphora lineolata	*Amphora lineolate* (Ehrenberg) Ehrenberg			+	+			+					+							+	+	*	–
	Amphora mutabunda	*Amphora mutabunda* Manguin																				+	–	–
	Amphora ovalis	*Amphora ovalis* (Kützing) Kützing				+																	*	4
	Navicula tuscula	*Aneumastus tusculus* (Ehrenberg) D.G.Mann & A.J.Stickle																				+	3	–
	Anomoeoneis sphaerophora	*Anomoeoneis sphaerophora* Pfitzer				+								+									*	–
	Asterionella formosa	*Asterionella formosa* Hassall																				+	*	4
	Asterionella gracillima	*Asterionella tekelili* D.M.Williams, T.M.Schuster, E.Cesar & Jüttner															+						–	–
	Melosira granulata	*Aulacoseira granulata* (Ehrenberg) Simonsen																				+	*	4
	Melosira italica	*Aulacoseira italica* (Ehrenberg) Simonsen																				+	G	3
	Bacillaria paradoxa	*Bacillaria paxillifera* (O.F.Müller) T.Marsson	+	+													+						*	5
	Anomoeoneis exilis	*Brachysira exilis* (Kützing) Round & D.G.Mann							+														–	–
	Anomoeoneis serians	*Brachysira serians* (Brébisson) Round & D.G.Mann								+													2	–
	Cymbella lanceolata	*Brebissonia lanceolate* (C.Agardh) R.K.Mahoney & Reimer																				+	–	–
	Caloneis alpestris	*Caloneis alpestris* (Grunow) Cleve																				+	G	–
	Caloneis bacillum	*Caloneis bacillum* (Grunow) Cleve																				+	D	3
	Caloneis beccariana	*Caloneis beccariana* (Grunow) Grunow ex Cleve																				+	–	–
	Caloneis macedonica	*Caloneis budensis* (Grunow) Krammer																				+	R	–
	Caloneis clevei	*Caloneis clevei* (Lagerstedt) Cleve																				+	–	–
	Caloneis desertorum	*Caloneis desertorum* Hustedt				+																	–	–
	Caloneis fasciata	*Caloneis fasciata* (Lagerstedt) Cleve																				+	–	–
	Pinnularia leptosoma	*Caloneis leptosoma* (Grunow) Krammer	+			+	+	+	+	+	+	+	+		+	+	+		+	+	+		G	–
	Navicula limosa	*Caloneis limosa* (Kützing) R.M.Patrick								+	+												–	–
	Pinnularia molaris	*Caloneis molaris* (Grunow) Krammer																				+	*	–
	Caloneis permagna	*Caloneis permagna* (Bailey) Cleve																			+		D	–
	Caloneis schumanniana	*Caloneis schumanniana* (Grunow) Cleve																				+	3	–
	Caloneis silicula	*Caloneis silicula* (Ehrenberg) Cleve																				+	*	3
	Pinnularia undulata	*Caloneis undosa* Krammer								+													–	–
	Navicula cocconeiformis	*Cavinula cocconeiformis* (W.Gregory ex Greville) D.G.Mann & A.J.Stickle																				+	*	–
	Navicula variostriata	*Cavinula variostriata* (Krasske) D.G.Mann & A.J.Stickle																				+	3	–
	Navicula begeri	*Chamaepinnularia begeri* (Krasske) Lange-Bertalot																				+	G	–

Appendix 1. (Continued)

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Navicula ignobilis*	*Chamaepinnularia krookii* (Grunow) Lange-Bertalot & Krammer																				+	R	–
	Cocconeis diminuta	*Cocconeis neodiminuta* Krammer																				+	*	3
	Cocconeis thumensis	*Cocconeis neothumensis* Krammer																				+	*	–
	Cocconeis pediculus	*Cocconeis pediculus* Ehrenberg			+	+											+						*	4
	Cocconeis placentula	*Cocconeis placentula* Ehrenberg	+								+												D	4
	Cocconeis scutellum	*Cocconeis scutellum* Ehrenberg				+			+	+	+												*	–
	Navicula accomoda	*Craticula accomoda* (Hustedt) D.G.Mann																				+	*	5
	Navicula ambigua	*Craticula ambigua* (Ehrenberg) D.G.Mann			+	+																	*	–
	Navicula cuspidata	*Craticula cuspidata* (Kutzing) D.G.Mann														+							*	4
	Navicula halophila	*Craticula halophila* (Grunow) D.G.Mann			+																		*	4
	Navicula simplex	*Craticula simplex* (Krasske) Levkov																				+	–	–
	Navicula molesta	*Craticula zizix* (VanLandingham) Guiry							+														–	–
	Synedra pulchella	*Ctenophora pulchella* (Kützing) D.M.Williams & Round					+	+															*	4
	Cyclotella comata	*Cyclotella comata* (Her.) Kützing	+	+																			–	5
	Cyclotella striata	*Cyclotella striata* (Kützing) Grunow		+			+	+					+			+	+			+			*	–
	Cymatopleura elliptica	*Cymatopleura* elliptica (Brébisson) W.Smith																				+	*	–
	Cymbella affinis	*Cymbella affinis* Kützing												+									2	2
	Cymbella aspera	*Cymbella aspera* (Ehrenberg) Cleve																				+	G	2
	Cymbella cistula	*Cymbella cistula* (Ehrenberg) O.Kirchner																				+	–	–
	Cymbella cymbiformis	*Cymbella cymbiformis* C.Agardh			+																		3	–
	Cymbella edelbergii	*Cymbella edelbergii* Foged																				+	–	–
	Cymbella farakulumensis	*Cymbella farakulumensis* Foged																				+	–	–
	Cymbella haslundii	*Cymbella haslundii* Foged																				+	–	–
	Cymbella helmandensis	*Cymbella helmandensis* Foged																				+	–	–
	Cymbella helvetica	*Cymbella helvetica* Kützing			+				+														3	–
	Cymbella hustedtii	*Cymbella hustedtii* Krasske																				+	G	–
	Cymbella koeiei	*Cymbella koeiei* Foged																				+	–	–
	Cymbella kolbei	*Cymbella kolbei* Hustedt																				+	R	–
	Cymbella laevis	*Cymbella laevis* Nägeli																				+	3	–
	Navicula lanceolata	*Cymbella lanceolata* C.Agardh																				+	–	3
	Cymbella leptoceros	*Cymbella neoleptoceros* Krammer				+	+			+		+	+	+		+	+		+				*	–
	Cymbella obtusa	*Cymbella obtusa* W.Gregory																				+	–	–
	Cymbella obtusiuscula	*Cymbella obtusiuscula* Kützing																				+	–	–
	Cymbella panjaoensis	*Cymbella panjaoensis* Foged																				+	–	–
	Cymbella parva	*Cymbella parva* (W.Smith) Kirchner																				+	G	–
	Cymbella sabzewarensis	*Cymbella sabzewarensis* Foged																				+	–	–
	Cymbella stuxbergii	*Cymbella stuxbergii* (Cleve) Cleve			+	+			+														–	–
	Cymbella tumida	*Cymbella tumida* (Brébisson) Van Heurck																				+	*	3
	Cymbella tumidula	*Cymbella tumidula* Grunow																				+	–	–
	Cymbella amphicephala	*Cymbopleura amphicephala* (Nägeli ex Kützing) Krammer																				+	G	2
	Cymbella angustata	*Cymbopleura angustata* (W.Smith) Krammer																				+	*	–
	Cymbella cuspidata	*Cymbopleura cuspidata* (Kützing) Krammer																				+	G	–
	Cymbella ehrenbergii	*Cymbopleura inaequalis* (Ehrenberg) Krammer																				+	V	–
	Cymbella lata	*Cymbopleura lata* (Grunow ex Cleve) Krammer																				+	3	–
	Cymbella naviculiformis	*Cymbopleura naviculiformis* (Auerswald ex Heiberg) Krammer																				+	*	3

Appendix 1. (Continued)

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Cymbella rupicola*	*Cymbopleura rupicola* (Grunow) Krammer																				+	G	–
	Cymbella similis	*Cymbopleura similis* (Krasske) Krammer	+				+		+				+	+		+			+				G	–
	Cymbella delicatula	*Delicatophycus delicatulus* (Kützing) M.J.Wynne																				+		2
	Denticula subtilis	*Denticula subtilis* Grunow				+																	*	4
	Denticula tenuis	*Denticula tenuis* Kützing																				+	*	2
	Denticula thermalis	*Denticula thermalis* Kützing			+																		R	–
	Diatoma elongatum	*Diatoma elongata* f. lata Serbanescu & Serbanescu				+						+	+						+				–	–
	Diatoma vulgare	*Diatoma vulgaris* Bory																				+	*	3
	Diatomella balfouriana	*Diatomella balfouriana* Greville			+	+	+		+	+	+			+		+				+			G	2
	Didymosphenia geminata	*Didymosphenia geminata* (Lyngbye) Mart.Schmidt				+																	*	2
	Diploneis elliptica	*Diploneis elliptica* (Kützing) Cleve	+				+	+															V	3
	Diploneis interrupta	*Diploneis interrupta* (Kützing) Cleve																			+		*	–
	Diploneis oculata	*Diploneis oculata* (Brébisson) Cleve																				+	*	–
	Diploneis ovalis	*Diploneis ovalis* (Hilse) Cleve																		+	+		2	3
	Diploneis puella	*Diploneis puella* (Schumann) Cleve																				+	D	–
	Diploneis smithii	*Diploneis smithii* (Brébisson) Cleve			+						+					+							*	–
	Navicula kotschyi	*Dorofeyukea kotschy* (Grunow) Kulikovskiy, Kociolek, Tusset & T.Ludwig																				+	D	4
	Melosira arenaria	*Ellerbeckia arenaria* (D.Moore ex Ralfs) Dorofeyuk & Kulikovskiy																				+	*	2
	Cymbella turgida	*Encyonema elginense* (Krammer) D.G.Mann																				+	2	–
	Cymbella gracilis	*Encyonema gracile* Rabenhorst																				+	–	–
	Cymbella latens	*Encyonema latens* (Krasske) D.G.Mann																				+	0	–
	Cymbella prostrata	*Encyonema leibleinii* (C.Agardh) W.J.Silva, R.Jahn, T.A.V.Ludwig & M.Menezes																				+	*	–
	Cymbella obscura	*Encyonema obscurum* (Krasske) D.G.Mann																				+	3	–
	Cymbella perpusilla	*Encyonema perpusillum* (A.Cleve) D.G.Mann	+		+	+	+	+															3	–
	Cymbella ventricosa	*Encyonema ventricosum* (C.Agardh) Grunow									+												*	–
	Cymbella cesati	*Encyonopsis cesatii* (Rabenhorst) Krammer																				+	V	2
	Cymbella delicatissima	*Encyonopsis delicatissima* (Hustedt) Krammer																				+	–	–
	Navicula descripta	*Encyonopsis descripta* (Hustedt) Krammer																				+	G	–
	Navicula falaisensis	*Encyonopsis falaisensis* (Grunow) Krammer																				+	G	2
	Cymbella fonticola	*Encyonopsis fonticola* (Hustedt) Krammer									+												*	–
	Cymbella subalpina	*Encyonopsis mendosa* (Van Landingham) Da Silva & Menezes																				+	–	–
	Cymbella microcephala	*Encyonopsis microcephala* (Grunow) Krammer	+	+	+	+	+	+	+		+		+	+	+					+	+		*	3
	Amphiprora alata	*Entomoneis alata* (Ehrenberg) Ehrenberg					+	+									+			+	+		*	5
	Epithemia zebra	*Epithemia adnata* (Kützing) Brébisson																				+	*	2
	Epithemia argus	*Epithemia argus* (Ehrenberg) Kützing															+						*	–
	Epithemia alpestris	*Epithemia argus* var. alpestris (W.Smith) Grunow																				+	G	–
	Pinnularia gibba	*Epithemia gibba* (Ehrenberg) Kützing																				+	–	2
	Epithemia muelleri	*Epithemia muelleri* Fricke																				+	–	–
	Rhopalodia parallela	*Epithemia parallela* (Grunow) Ruck & Nakov																				+	–	–
	Epithemia sorex	*Epithemia sorex* Kützing																				+	*	2
	Epithemia turgida	*Epithemia turgida* (Ehrenberg) Kützing																				+	*	2
	Achnanthes flexella	*Eucocconeis flexella* (Kützing) F.Meister					+	+															2	2
	Eunotia arcus	*Eunotia arcus* Ehrenberg																				+	V	–
	Eunotia gracilis	*Eunotia exigua* (Brébisson ex Kützing) Rabenhorst												+									*	2
	Eunotia montana	*Eunotia montana* Hustedt																				+	–	–

Appendix 1. (Continued)

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Eunotia parallela*	*Eunotia parallela* Ehrenberg									+												–	–
	Eunotia praerupta	*Eunotia praerupta* Ehrenberg															+						2	–
	Eunotia rhomboidea	*Eunotia rhomboidea* Hustedt			+																		G	2
	Eunotia tenella	*Eunotia tenella* (Grunow) Hustedt							+														G	–
	Eunotia tschirchiana	*Eunotia tschirchiana* O.Müller									+												–	–
	Navicula insociabilis	*Fallacia insociabilis* (Krasske) D.G.Mann																				+	*	–
	Navicula omissa	*Fallacia omissa* (Hustedt) D.G.Mann																				+	D	–
	Navicula pygmaea	*Fallacia pygmaea* (Kützing) Stickle & D.G.Mann															+						*	5
	Navicula subhamulata	*Fallacia subhamulata* (Grunow) D.G.Mann			+																		*	4
	Navicula vitrea	*Fallacia vitrea* (Østrup) D.G.Mann			+	+					+									+			G	–
	Synedra amphicephala	*Fragilaria amphicephaloides* Lange-Bertalot																				+	3	–
	Fragilaria capucina	*Fragilaria capucina* Desmazières																				+	*	3
	Fragilaria crotonensis	*Fragilaria crotonensis* Kitton	+																				*	3
	Synedra rumpens	*Fragilaria rumpens* (Kützing) G.W.F.Carlson																				+	*	–
	Synedra tenera	*Fragilaria tenera* (W.Smith) Lange-Bertalot																				+	*	3
	Fragilaria vaucheriae	*Fragilaria vaucheriae* (Kützing) J.B.Petersen	+								+												*	3
	Fragilaria virescens	*Fragilariforma virescens* (Ralfs) D.M.Williams & Round															+						*	2
	Frustulia rhomboides	*Frustulia rhomboides* (Ehrenberg) De Toni				+																	–	–
	Frustulia vulgaris	*Frustulia vulgaris* (Thwaites) De Toni	+	+			+	+												+			*	4
	Navicula schoenfeldii	*Geissleria schoenfeldii* (Hustedt) Lange-Bertalot & Metzeltin																				+	*	–
	Navicula digitulus	*Genkalia digitulus* (Hustedt) Lange-Bertalot & Kulikovskiy																				+	3	2
	Achnanthes exigua	*Gogorevia exilis* (Kützing) Kulikovskiy & Kociolek				+				+													–	4
	Gomphonema clevei	*Gomphoneis clevei* (Fricke) Gil																				+	–	–
	Gomphonema olivaceum	*Gomphonella olivacea* (Hornemann) Rabenhorst																				+	–	3
	Gomphonema olivaceoides	*Gomphonella olivaceoides* (Hust.) Tuji			+				+														–	–
	Gomphonema acuminatum	*Gomphonema acuminatum* Ehrenberg																				+	*	3
	Gomphonema longiceps	*Gomphonema acuminatum* var. longiceps (Ehrenberg) N.Abarca & R.Jahn				+																	*	–
	Gomphonema angustatum	*Gomphonema angustatum* (Kützing) Rabenhorst	+																				*	3
	Gomphonema constrictum	*Gomphonema constrictum* Ehrenberg				+					+												–	–
	Gomphonema dichotomum	*Gomphonema dichotomum* Kützing					+	+															V	–
	Gomphonema farakulumensis	*Gomphonema farakulumense* Foged																				+	–	–
	Gomphonema gracile	*Gomphonema gracile* Ehrenberg				+																	D	–
	Gomphonema lanceolatum	*Gomphonema grunowii* R.M.Patrick & Reimer																	+				–	–
	Gomphonema helveticum	*Gomphonema helveticum* Brun																				+	–	–
	Gomphonema intricatum	*Gomphonema intricatum* Kützing				+										+	+				+		–	–
	Gomphonema parvulum	*Gomphonema parvulum* (Kützing) Kützing			+																		*	4
	Gomphonema vamaensis	*Gomphonema vamaensis* Foged																				+	–	–
	Gomphonema hedinii	*Gomphosinica hedinii* (Hustedt) Kociolek, Q.-M.You, Q.-X.Wang & Q.Liu																				+	–	–
	Nitzschia sinuata	*Grunowia sinuata* (Thwaites ex W.Smith) Rabenhorst																				+	–	2
	Gyrosigma spenceri	*Gyrosigma acuminatum* (Kützing) Rabenhorst																				+	*	4
	Gyrosigma attenuatum	*Gyrosigma attenuatum* (Kützing) Rabenhorst																				+	*	5
	Gyrosigma distortum	*Gyrosigma distortum* (W.Smith) J.W.Griffith & Henfrey	+																				–	–
	Gyrosigma scalproides	*Gyrosigma scalproides* (Rabenhorst) Cleve				+																	–	4
	Amphora coffeiformis	*Halamphora coffeiformis* (C.Agardh) Mereschkowsky	+																				*	4
	Amphora dubiosa	*Halamphora dubiosa* (Østrup) Levkov													+	+							–	–

Appendix 1. (Continued)

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Amphora triundulata*	*Halamphora dusenii* (Brun) Levkov																				+	D	–
	Amphora obscura	*Halamphora obscura* Levkov																				+	D	–
	Amphora schroederi	*Halamphora schroederi* (Hustedt) Levkov																				+	–	–
	Amphora submontana	*Halamphora submontana* (Hustedt) Levkov																				+	–	–
	Amphora veneta	*Halamphora veneta* (Kützing) Levkov												+									*	5
	Ceratoneis arcus	*Hannaea arcus* (Ehrenberg) R.M.Patrick			+							+											V	2
	Hantzschia amphioxys	*Hantzschia amphioxys* (Ehrenberg) Grunow					+																*	4
	Navicula hungarica	*Hippodonta hungarica* (Grunow) Lange-Bertalot, Metzeltin & Witkowski															+				+		*	5
	Navicula contenta	*Humidophila contenta* Grunow) Lowe, Kociolek, Johansen, Van de Vijver, Lange-Bertalot & Kopalová																				+	D	–
	Navicula perpusilla	*Humidophila perpusilla* (Grunow) R.L.Lowe, Kociolek, J.R.Johansen, Van de Vijver, Lange-Bertalot & Kopalová			+	+				+	+			+	+								*	–
	Pinnularia balfouriana	*Hygropetra balfouriana* (Grunow ex Cleve) Krammer & Lange-Bertalot																				+	G	–
	Surirella linearis	*Iconella linearis* (W.Smith) Ruck & Nakov																				+	–	–
	Surirella tenera	*Iconella tenera* (W.Gregory) Ruck & Nakov																				+	–	–
	Achnanthes clevei	*Karayevia clevei* (Grunow) Bukhtiyarova																				+	*	3
	Achnanthes plönensis	*Karayevia ploenensis* (Hustedt) Bukhtiyarova																				+	*	–
	Achnanthes hungarica	*Lemnicola hungarica* (Grunow) Round & Basson																				+	*	4
	Cyclotella comta	*Lindavia comta* (Kützing) T.Nakov & al																				+	–	–
	Navicula cohnii	*Luticola cohnii* (Hilse) D.G.Mann								+													V	–
	Navicula lagerstedtii	*Luticola lagerheimii* (Cleve) D.G.Mann																				+	–	–
	Navicula mutica	*Luticola mutica* (Kützing) D.G.Mann									+												*	–
	Mastogloia braunii	*Mastogloia braunii* Grunow									+												*	–
	Mastogloia grevillei	*Mastogloia danseyi* f. grevillea (W.Smith) Edlund & Burge																				+	*	–
	Mastogloia elliptica	*Mastogloia elliptica* (C.Agardh) Cleve															+				+		*	3
	Mastogloia exigua	*Mastogloia exigua* F.W.Lewis					+														+		–	–
	Mastogloia smithii	*Mastogloia smithii* Thwaites ex W.Smith		+	+	+	+		+		+	+	+	+	+	+	+				+		*	–
	Navicula permitis	*Mayamaea permitis* (Hustedt) K.Bruder & Medlin																				+	*	–
	Melosira varians	*Melosira varians* C.Agardh																				+	*	4
	Meridion circulare	*Meridion circulare* (Greville) C.Agardh	+				+	+		+	+			+						+			*	2
	Navicula gibbula	*Muelleria gibbula* (Cleve) Spaulding & Stoermer	+	+	+	+	+	+	+		+			+					+				G	–
	Navicula disjuncta	*Myriactula pulvinata* (Kützing) Kuntze																				+	–	–
	Navicula accurata	*Navicula accurata* Hustedt																				+	–	–
	Navicula anderabensis	*Navicula anderabensis* Foged																				+	–	–
	Navicula bannajensis	*Navicula bannajensis* J.B.Petersen																				+	–	–
	Navicula chasmaensis	*Navicula chasmaensis* Foged																				+	–	–
	Navicula cincta	*Navicula cincta* (Ehrenberg) Ralfs	+																				*	5
	Navicula cinctiformis	*Navicula cinctiformis* Hustedt					+			+			+										–	–
	Navicula cryptocephala	*Navicula cryptocephala* Kützing	+				+	+															*	4
	Navicula digitoradiata	*Navicula digitoradiata* (W.Gregory) Ralfs	+				+																*	–
	Navicula exigua	*Navicula exigua* W.Gregory, nom. illeg																				+	–	–
	Navicula faceta	*Navicula faceta* Hustedt																				+	–	–
	Navicula farakulumensis	*Navicula farakulumensis* Foged																				+	–	–
	Navicula gregaria	*Navicula gregaria* Donkin																				+	*	4
	Navicula helmandensis	*Navicula helmandensis* Foged																				+	–	–
	Navicula koeiei	*Navicula koeiei* Foged																				+	–	–

Appendix 1. (Continued)

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Navicula kuripanensis*	*Navicula kuripanensis* Hustedt																				+	–	–
	Navicula paulseniana	*Navicula lacustris* var. *paulseniana* (J.B.Petersen) Zabelina																				+	*	–
	Navicula menisculus	*Navicula menisculus* Schumann																				+	*	4
	Navicula monodi	*Navicula monodi* Guermeur																				+	–	–
	Navicula oblonga	*Navicula oblonga* (Kützing) Kützing																				+	G	4
	Navicula oblongata	*Navicula oblongata* Kützing																				+	–	–
	Navicula peregrina	*Navicula peregrina* (Ehrenberg) Kützing																+					*	5
	Navicula praeterita	*Navicula praeterita* Hustedt																				+	2	–
	Navicula pseudannulata	*Navicula pseudannulata* Frenguelli																+					–	–
	Navicula pseudogracilis	*Navicula pseudogracilis* Hustedt																			+		–	–
	Navicula radiosa	*Navicula radiosa* Kützing																				+	*	4
	Navicula ramosissima	*Navicula ramosissima* (C.Agardh) Cleve	+	+	+		+	+			+	+				+			+				–	–
	Navicula rhynchocephala	*Navicula rhynchocephala* Kützing																				+	*	4
	Navicula salinarum	*Navicula salinarum* Grunow	+													+							*	5
	Navicula seminoides	*Navicula seminoides* Cleve																				+	–	–
	Navicula certa	*Navicula splendicula* VanLandingham																				+	G	–
	Navícula subrhynchocephala	*Navicula subrhynchocephala* Hustedt																				+	R	3
	Navicula gracilis	*Navicula tripunctata* (O.F.Müller) Bory																				+	*	5
	Navicula veneta	*Navicula veneta* Kützing																				+	*	4
	Navicula viridula	*Navicula viridula* (Kützing) Ehrenberg																				+	*	5
	Cymbella pusilla	*Navicymbula pusilla* (Grunow) Krammer												+									*	–
	Navicula decussis	*Navigeia decussis* (Østrup) Bukhtiyarova																				+	–	–
	Neidium binode	*Neidiomorpha binodis* (Ehrenberg) M.Cantonati, Lange-Bertalot & N.Angeli																				+	V	–
	Neidium affine	*Neidium affine* (Ehrenberg) Pfitzer															+						V	–
	Neidium bisulcatum	*Neidium bisulcatum* (Lagerstedt) Cleve																				+	3	–
	Neidium iridis	*Neidium iridis* (Ehrenberg) Cleve																				+	2	–
	Nitzschia acicularis	*Nitzschia acicularis* (Kützing) W.Smith																				+	*	4
	Nitzschia subfrustulum	*Nitzschia aequorea* Hustedt																				+	*	–
	Nitzschia amphibia	*Nitzschia amphibia* Grunow			+																+		*	5
	Nitzschia amphibioides	*Nitzschia amphibioides* Hustedt																				+	–	–
	Nitzschia anderabensis	*Nitzschia anderabensis* Foged																				+	–	–
	Nitzschia bacillariaeformis	*Nitzschia bacillariaeformis* Hustedt																			+		*	–
	Nitzschia communis	*Nitzschia communis* Rabenhorst					+	+															*	5
	Nitzschia commutata	*Nitzschia commutata* Grunow							+							+	+						*	–
	Nitzschia denticula	*Nitzschia denticula* Grunow					+																V	–
	Nitzschia dissipata	*Nitzschia dissipata* (Kützing) Rabenhorst																				+	*	3
	Nitzschia dubia	*Nitzschia dubia* W.Smith													+								*	–
	Nitzschia romana	*Nitzschia fonticola* (Grunow) Grunow															+						*	4
	Nitzschia frustulum	*Nitzschia frustulum* (Kützing) Grunow																				+	*	3
	Nitzschia gruendleri	*Nitzschia gruendleri* Grunow	+																				–	–
	Nitzschia terricola	*Nitzschia harderi* Hustedt																				+	R	–
	Nitzschia heidenii	*Nitzschia heidenii* (F.Meister) Hustedt, nom. inval															+						–	–
	Nitzschia intermedia	*Nitzschia intermedia* Hantzsch ex Cleve & Grunow																				+	*	3
	Nitzschia invisitata	*Nitzschia invisitata* Hustedt																				+	–	–
	Nitzschia linearis	*Nitzschia linearis* W.Smith															+						*	3
	Nitzschia mahihaensis	*Nitzschia mahihaensis* Foged																				+	–	–

Appendix 1. (Continued)

PHYLUM	Synonym species from articles	Current accepted name from Algaebase (2024)	Upper Helmand River	Upper Herat River (Hari Rud1)	Band-i Amir (Bamyan province)	Panjao small River	Sar-i Chasma	Panjshir River	Shin Dand (Sabzewar) River	Girishk River	Andarab River	Dilaram. River (The Khash Rud)	Mokur. Canal	Lal-i-Sarjangel (Upper Hari Rud)	Murghab-Maimana	Qala Nau-Murghab	Nuristan (Kuner River)	Sar-i chashma Chashmaishir and Shamarq	Hari Rud River2	Upper Helmand3Hauz-i-Mahiha	Upper Helmand Rud2 (Farakulum)	indereminate sampling place country	RL	BCG
Heterokontophyta	*Nitzschia maxima*	*Nitzschia maxima* Grunow	+																				*	–
	Nitzschia microcephala	*Nitzschia microcephala* Grunow																				+	*	5
	Nitzschia ignorata	*Nitzschia nana* Grunow					+						+							+			*	–
	Nitzschia obsidialis	*Nitzschia obsidialis* Hustedt																				+	–	–
	Nitzschia obtusa	*Nitzschia obtusa* W.Smith			+	+							+	+		+							*	–
	Nitzschia palea	*Nitzschia palea* (Kützing) W.Smith					+				+						+			+	+		*	5
	Nitzschia paleacea	*Nitzschia paleacea* (Grunow) Grunow					+	+									+			+	+		*	3
	Nitzschia paleaeformis	*Nitzschia paleaeformis* Hustedt																				+	G	–
	Nitzschia ostenfeldii	*Nitzschia pamirensis* Hustedt	+			+	+		+	+	+					+							–	–
	Nitzschia salinicola	*Nitzschia salinicola* Aleem & Hustedt																				+	–	–
	Nitzschia sigma	*Nitzschia sigma* (Kützing) W.Smith							+						+								*	4
	Nitzschia sigmoidea	*Nitzschia sigmoidea* (Nitzsch) W.Smith																				+	*	4
	Nitzschia amphioxoides	*Nitzschia subamphioxoides* Hustedt																				+	–	–
	Nitzschia valida	*Nitzschia valida* Cleve & Grunow			+				+			+	+			+							–	–
	Nitzschia vana	*Nitzschia vana* Cholnoky																				+	–	–
	Nitzschia vermicularis	*Nitzschia vermicularis* (Kützing) Hantzsch	+				+	+						+						+			*	–
	Nitzschia vitrea	*Nitzschia vitrea* G.Norman																		+			*	–
	Diatoma hyemalis	*Odontidium hyemale* (Roth) Kützing			+																		–	–
	Melosira roeseana	*Orthoseira roeseana* (Rabenhorst) Pfitzer									+					+							D	3
	Cyclotella kuetzingiana	*Pantocsekiella kuetzingiana* (Thwaites) K.T.Kiss & E.Ács									+												*	–
	Navicula appendiculata	*Pinnularia appendiculata* (C.Agardh) Schaarschmidt	+	+													+			+	+		*	–
	Pinnularia borealis	*Pinnularia borealis* Ehrenberg																				+	*	3
	Navicula brebissonii	*Pinnularia brebissonii* (Kützing) Rabenhorst	+			+			+						+	+							*	–
	Pinnularia divergens	*Pinnularia divergens* W.Smith									+					+							V	–
	Pinnularia gentilis	*Pinnularia gentilis* (Donkin) Cleve																				+	G	–
	Pinnularia gracillima	*Pinnularia gracillima* W.Gregory													+	+				+			–	–
	Pinnularia intermedia	*Pinnularia intermedia* (Lagerstedt) Cleve																				+	3	–
	Pinnularia interrupta	*Pinnularia interrupta* W.Smith			+																		–	–
	Pinnularia kneuckeri	*Pinnularia kneuckeri* Hustedt			+	+																	R	–
	Pinnularia lata	*Pinnularia lata* (Brébisson) W.Smith																				+	3	–
	Pinnularia mesolepta	*Pinnularia mesolepta* (Ehrenberg) W.Smith																				+	–	–
	Pinnularia microstauron	*Pinnularia microstauron* (Ehrenberg) Cleve																				+	V	3
	Pinnularia parva	*Pinnularia parva* Ehrenberg																				+	–	–
	Pinnularia saxicola	*Pinnularia saxicola* J.W.G.Lund																				+	–	–
	Pinnularia silvatica	*Pinnularia silvatica* J.B.Petersen																+					D	–
	Navicula tabellaria	*Pinnularia tabellaria* Ehrenberg															+						–	–
	Pinnularia tibetana	*Pinnularia tibetana* Hustedt							+							+							–	–
	Navicula viridis	*Pinnularia viridis* (Nitzsch) Ehrenberg	+				+		+														D	–
	Navicula abiskoensis	*Placoneis abiskoensis* (Hustedt) Lange-Bertalot & Metzeltin																				+	R	3
	Navicula dicephala	*Placoneis dicephala* (Ehrenberg) Mereschkowsky																				+	–	–
	Dimeregramma minus	*Plagiogramma minus* (W.Gregory) Chunlian Li, Ashworth & Witkowski							+		+				+	+	+		+				–	–
	Plagiogramma pulchellum	*Plagiogramma pulchellum* Greville			+																		–	–
	Achnanthes hauckiana	*Planothidium hauckianum* (Grunow) Bukhtiyarova																				+	G	–
	Achnanthes grimmei	*Planothidium grimmei* (Krasske) I.W.Bishop & Spaulding				+																	–	–
	Achnanthes lanceolata	*Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot									+					+							*	4

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Heterokontophyta	*Achnanthes conspicua*	*Platessa conspicua* (Ant.Mayer) Lange-Bertalot	+				+										+						*	3
	Pleurosigma elongatum	*Pleurosigma elongatum* W.Smith															+						*	–
	Navicula ventralis	*Psammothidium ventral* (Krasske) Bukhtiyarova & Round, nom. inval.															+			+			2	–
	Fragilaria brevistriata	*Pseudostaurosira brevistriata* (Grunow) D.M.Williams & Round																				+	*	3
	Synedra parasitica	*Pseudostaurosira parasitica* (W.Smith) E.Morales																				+	*	4
	Cymbella sinuata	*Reimeria sinuata* (W.Gregory) Kociolek & Stoermer																				+	*	2
	Rhoicosphenia curvata	*Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot																				+	*	3
	Rhopalodia gibberula	*Rhopalodia gibberula* (Ehrenberg) O.Müller														+							D	–
	Rhopalodia musculus	*Rhopalodia musculus* (Kützing) O.Müller				+																	*	–
	Navicula bacillum	*Sellaphora bacillum* (Ehrenberg) D.G.Mann																				+	*	2
	Navicula pseudoventralis	*Sellaphora pseudoventralis* (Hustedt) Chudaev & Gololobova																				+	–	–
	Navicula pupula	*Sellaphora pupula* (Kützing) Mereschkovsky																				+	D	3
	Navicula stroemii	*Sellaphora stroemii* (Hustedt) H.Kobayasi																				+	2	3
	Navicula submuralis	*Sellaphora submuralis* (Hustedt) C.E.Wetzel, Ector, B.Van de Vijver, Compère & D.G.Mann																				+	–	–
	Navicula tridentula	*Sellaphora tridentula* (Krasske) C.E.Wetzel																				+	–	–
	Stauroneis agrestis	*Stauroneis agrestis* J.B.Petersen				+										+					+		R	–
	Stauroneis anceps	*Stauroneis anceps* Ehrenberg																				+	V	3
	Stauroneis kriegeri	*Stauroneis kriegeri* R.M.Patrick																				+	*	3
	Stauroneis phoenicenteron	*Stauroneis phoenicenteron* (Nitzsch) Ehrenberg												+									V	3
	Stauroneis smithii	*Stauroneis smithii* Grunow																				+	*	4
	Stauroneis sphaerophora	*Stauroneis sphaerophora* Ehrenberg																				+	–	–
	Stauroneis palustris	*Staurophora tackei* (Hustedt) Bahls																				+	–	–
	Fragilaria construens	*Staurosira construens* Ehrenberg														+							*	4
	Fragilaria leptostauron	*Staurosira leptostauron* (Ehrenberg) Kulikovskiy & Genkal																				+	–	–
	Fragilaria pinnata	*Staurosirella pinnata* (Ehrenberg) D.M.Williams & Round		+		+				+	+					+				+	+		–	4
	Cyclotella meneghiniana	*Stephanocyclus meneghinianus* (Kützing) Kulikovskiy,Genkal & Kociolek		+																	+		*	5
	Stephanodiscus astraea	*Stephanodiscus astraea* (Kützing) Grunow																				+	–	–
	Surirella angusta	*Surirella angusta* Kützing																				+	*	4
	Cymatopleura solea	*Surirella librile* (Ehrenberg) Ehrenberg																				+	–	4
	Suriraya ovalis	*Surirella ovalis* *Brébisson*																			+		*	5
	Surirella robusta	*Surirella robusta* Ehrenberg																				+	3	–
	Tabellaria fenestrata	*Tabellaria fenestrata* (Lyngbye) Kützing																				+	V	2
	Tabellaria flocculosa	*Tabellaria flocculosa* (Roth) Kützing																				+	*	2
	Synedra tabulata	*Tabularia tabulata* (C.Agardh) Snoeijs																				+	*	3
	Nitzschia angustata	*Tryblionella angustata* W.Smith																				+	–	–
	Nitzschia apiculata	*Tryblionella apiculata* W.Gregory	+				+									+		+			+		–	4
	Nitzschia tryblionella	*Tryblionella hantzschiana* Grunow													+	+	+						–	–
	Nitzschia hungarica	*Tryblionella hungarica* (Grunow) Frenguelli							+		+				+	+					+		–	5
	Synedra acus	*Ulnaria acus* (Kützing) Aboal																				+	*	–
	Synedra capitata	*Ulnaria capitata* (Ehrenberg) Compère																				+	*	–
	Synedra ulna	*Ulnaria ulna* (Nitzsch) Compère	+	+	+	+	+				+					+				+			D	–

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Charophyta	*Closterium cornu*	*Closterium cornu* Ehrenberg ex Ralfs																				+	3	–
	Coleochaete scutata	*Coleochaete scutata* Brébisson																				+	–	–
	Cosmarium abruptum	*Cosmarium abruptum* P.Lundell																				+	–	–
	Cosmarium aitchisonii	*Cosmarium aitchisonii* Schaarschmidt																				+	–	–
	Cosmarium botrytis	*Cosmarium botrytis* Meneghini ex Ralfs																				+	V	–
	Cosmarium minutum	*Cosmarium contractum* var. minutum (Delponte) Coesel																				+	3	–
	Cosmarium granatum	*Cosmarium granatum* Brébisson ex Ralfs																				+	*	–
	Cosmarium hookeri	*Cosmarium hookeri* Schaarschmidt																				+	–	–
	Cosmarium meneghinii	*Cosmarium meneghinii* Brébisson ex Ralfs																				+	V	–
	Cosmarium oliveri	*Cosmarium oliveri* Schaarschmidt																				+	–	–
	Cosmarium pulcherrimum	*Cosmarium pulcherrimum* Nordstedt																				+	–	–
	Cosmarium pyramidatum	*Cosmarium pyramidatum* Brébisson ex Ralfs																				+	3	–
	Cosmarium undulatum	*Cosmarium undulatum* Corda ex Ralfs																				+	3	–
	Desmidium quadratum	*Desmidium quadratum* Nordstedt																				+	3	–
	Euastrum spinulosum	*Euastrum spinulosum* Delponte																				+	2	–
	Spirogyra mirabilis	*Spirogyra mirabilis* (Hassall) Kützing																				+	–	–
	Spirogyra porticalis	*Spirogyra porticalis* (O.F.Müller) Dumortier																				+	–	–
	Spirogyra punctata	*Temnogyra punctata* (Cleve) Yamagishi																				+	–	–
Chlorophyta	*Bulbochaete pygmaea*	*Bulbochaete pygmaea* Pringsheim ex Hirn																				+	–	–
	Chlamydomonas minutissima	*Chlamydomonas minutissima* Korshikov																+					–	–
	Chlorella vulgaris	*Chlorella vulgaris* Beijerinck																+					–	–
	Chlorococcum infusionum	*Chlorococcum infusionum* (Schrank) Meneghini																+					–	–
	Chlorella ellipsoidea	*Chloroidium ellipsoideum* (Gerneck) Darienko & al																+					–	–
	Dactylococcus infusionum	*Dactylococcus infusionum* Nägeli																+					–	–
	Desmococcus olivaceus	*Desmococcus olivaceus* (Persoon ex Acharius) J.R.Laundon																				+	–	–
	Chlamydomonas debaryana	*Edaphochlamys debaryana* (Goroschankin) Pröschold & Darienko																				+	–	–
	Gloeocystis vesiculosa	*Gloeocystis vesiculosa* Nägeli																+					–	–
	Oedogonium pringsheimii	*Oedogonium pringsheimii* C.E.Cramer ex Hirn																				+	–	–
	Oocystis geminata	*Oocystis geminata* Nägeli ex A.Braun																				+	–	–
	Pandorina morum	*Pandorina morum* (O.F.Müller) Bory																				+	–	–
	Pleurococcus mucosus	*Pleurococcus mucosus* (Kützing) Rabenhorst																				+	–	–
	Pediastrum boryanum	*Pseudopediastrum boryanum* (Turpin) E.Hegewald																+					–	–
	Scenedesmus quadricauda	*Scenedesmus quadricauda* (Turpin) Brébisson																				+	–	–
	Scenedesmus acutus	*Tetradesmus obliquus* (Turpin) M.J.Wynne																+					–	–
	Conferva bombycina	*Tribonema bombycinum* (C.Agardh) Derbès & Solier																				+	–	–
Cyanobacteria	*Cylindrospermum licheniforme*	*Cylindrospermum licheniforme* Kützing ex Bornet & Flahault																+					–	–
	Gomphosphaeria aponina	*Gomphosphaeria aponina* Kützing																				+	–	–
	Oscillatoria chlorina	*Kamptonema chlorinum* (Kützing ex Gomont) Strunecký, Komárek & J.Smarda																+					–	–
	Phormidium autumnale	*Microcoleus autumnalis* (Gomont) Strunecky, Komárek & J.R.Johansen																+					–	–
	Nostoc commune	*Nostoc commune* Vaucher ex Bornet & Flahault																+					–	–
	Nostoc verrucosum	*Nostoc verrucosum* Vaucher ex Bornet & Flahault																+					–	–

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Cyanobacteria	*Oscillatoria brevis*	*Phormidium breve* (Kützing ex Gomont) Anagnostidis & Komárek																+					–	–
	Phormidium uncinatum	*Phormidium uncinatum* Gomont																+					–	–
	Pseudanabaena catenata	*Pseudanabaena catenata* Lauterborn																+					–	–
Ochrophyta	*Characiopsis anabaenae*	*Characiopsis anabaenae* Pascher																+					–	–
	Heterococcus caespitosus	*Heterococcus caespitosus* Vischer																+					–	–
	Polyedrium minimum	*Tetraëdron minimum* (A.Braun) Hansgirg																				+	–	–

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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Investigation of *Spirogyra daedaleoides* Czurda in terms of bioactive components

Spirogyra daedaleoides Czurda'nın biyoaktif bileşenler açısından incelenmesi

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Abstract: Algae stand out as suitable sources for use in the cosmetic, food and pharmaceutical industries due to their high content of components such as protein, polysaccharide, lipid, vitamin, mineral, amino acid, fatty acid, and carotenoid and due to the bioactive components that they produce. In this study, the bioactive properties of *Spirogyra daedaleoides* Czurda, located in the Charopyhta phylum of the algae, were examined. This species was isolated from the benthic habitats of the Yeşilırmak River and cultured. Antioxidant properties of *Spirogyra daedaleoides* was determined with the methods of free radical removal activity (DPPH, 2,2-diphenyl-1-picrylhydrazyl), iron (III) ion reduction power activity (FRAP, fluorescence recovery after photobleaching) and cation radical removal activity (ABTS, 2,2´-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)). The fatty acids of *Spirogyra daedaleoides* was determined by gas chromatography analysis, and vitamins were determined by high-performance liquid chromatography (HPLC) analysis. According to the results of antioxidant analysis, the free radical removal activity of *Spirogyra daedaleoides*, iron ion reduction power activity and cation radical removal activity were found to be high. When the fatty acid percentages of *Spirogyra daedaleoides* were considered, the ratios of C20:0 Arachidic acid, C16:0 Palmitic acid, C18:3n3 Alpha linoleic acid, C10:0 Caprinic acid and C18:2n6c Linoleic acid were found to be high. *Spirogyra daedaleoides* was found to be high in Vitamin A and Vitamin E. *Spirogyra daedaleoides* could be used as natural resources in the cosmetics, food and pharmaceutical industries according to the results.

Keywords: Charophyta, bioactive component, antioxidant, fatty acid, vitamin

INTRODUCTION

Algae are potential sources of bioactive secondary metabolites used in the development of new pharmaceutical substances. They are photosynthetic organisms found in both marine and freshwater environments**.**

Algae have been used in many different fields for many years. Due to the protein, carbohydrate, fatty acids, vitamins, minerals, pigments and many other important metabolites that accumulate in the cell, they are used by humans as the main nutritional support (Bulut, 2009). In addition to healthy nutrition, it is important for preventive treatment and the prevention of degenerative diseases with the help of antioxidants obtained from algae. Tocopherols, ascorbic acid, carotenoids, flavonoids and retinoids are the main antioxidants that can be found in algae (Baytaşoğlu and Başusta, 2015).

Bioactive sources of natural products have been used in the fight against diseases for hundreds of years, and the active ingredient of more than half of the drugs used today is formed from these sources (Rice-Evans et al., 1996).

Bioactive components are secondary metabolites that have positive effects on health by affecting physiological activities. Bioactive components, carbohydrates, proteins and fats which are known as primary metabolites, are not the main sources of essential nutrients for the growth and development of a living being. However, they are components that increase the ability of a living being to withstand harsh living conditions. Although bioactive components are usually found in small amounts in foods, they have serious health effects (Gupta et al., 2017). Microalgae produce bioactive components that are valuable products with applications in the cosmetics, food and pharmaceutical industries.

This study aimed to investigate the bioactive properties of *Spirogyra daedaleoides* included in the Charopyhta phylum. Since there are no previous studies on this species whose bioactive properties have been investigated and there is a trend towards natural sources of bioactive substances today, it was decided to conduct studies with this species.

MATERIALS AND METHODS

Isolating and culturing algae

Spirogyra daedaleoides Czurda 1932

Spirogyra: It is generally common in freshwater and benthic habitats. It can also be found in planktonic habitat. Thal structure can be found in the form of nested colonies. Tal structure consists of unbranched filaments. The cells are in single-row arrays. The cylindrical cells are 10 to >200 µm in

diameter and most are 20 to 60 µm long. The interior of the cells is cellulose and has a two-layered cell wall. There is a mucilage layer on the outside of the cells. Basal cells are rarely suitable for rhizoidal attachment. Cells are mononuclear. Chloroplasts are spiral shaped. Spiral fold is important in diagnosis. Akinetes and aplanospores are common; parthenospores are fewer. Asexual and sexual reproduction occurs. Sexual reproduction usually occurs through conjugation, typically in late spring and summer. The Phylum Charophyta is included in the Clade Zygnematophyceae. *Spirogyra daedaleoides* Czurda's synonym is *Spirogyra daedalea* f. *daedaloides* (Czurda) V. Poljansky. (Guiry and Guiry, 2024).

Empire: Eukaryota

Kingdom: Plantae

Phylum: Charophyta

Class: Zygnematophyceae

Subclass: Zygnematophycidae

Order: Spirogyrales

Family: Spirogyraceae

Genus: *Spirogyra*

Spirogyra daedaleoides was transported to the Laboratory and isolated by mechanical isolation method from water samples taken from Yeşilırmak River benthic habitats with plastic containers. The sampling point from Yeşilırmak is located in the city center of Tokat, at latitude 40˚ 21' 33.88" N and longitude 36˚38' 37.59" E. The samples were taken during the summer. The samples were transferred to eppendorf tubes under an inverted microscope, cultured and incubated at 26 °C (155 µmol/m2/h, L:D period) in Sanyo MLR 351 climate cabinet under Allen, BG11 liquid growth culture (Lobban et al., 1988; Andersen, 2005). After reaching a certain volumetric density, it was harvested and stored in a -86 °C freezer in a culture collection for research purposes.

For the identification of algae, several taxonomic literatures (Prescott, 1979; Canter-Lund & Lund, 1995; John et al., 2002) were used. In addition, the synonymous status and categories of the identified species were classified by checking the Algaebase database (Guiry and Guiry, 2024).

Fatty acid, vitamin analyses and antioxidant activity tests were applied after taking 5 g of the algae species extracted from the culture collection and extracting them in 150 mL solvent (1:1methanol+methylene chloride).

Antioxidant activity tests

In order to determine the antioxidant activity of the algae, three different methods have been applied.

Determination of DPPH free radical removal activity (DPPH-2,2-diphenyl-1-picrylhydrazyl)

The DPPH free radical removal activity of algal extracts and standard antioxidant substances was determined using the DPPH radical according to the Brand-Williams method (Brand-Williams et al., 1995). The solution of 20 mg/L DPPH was diluted with methanol and prepared on a regular basis. The 1.5 mL solution was taken and 0.75 ml of algae extract made in a range from 250 to 1000 mg per litre has been introduced into the solution. It was measured on a blind spectrophotometer per minute at an absorbance of 30 min. 517 nm. 0.75 mL methanol and 1.5 mL DPPH solution were used for control purposes. 6-hydroxy-2,5,7,8-tetramethyl chroman-2-carboxylic acid (Trolox), Butylated hydroxytoluene (BHT) and Butylated hydroxyanisole (BHA) were used as standard. Antioxidant analyses are based on the measurement of DPPH color loss at 517 nm following the reaction with test compounds, and the reaction was monitored with a spectrometer. A high free radical elimination activity is indicated by any decrease in the absorbance of the reaction mixture.

Determination of iron (III) ion reduction power activity (FRAP- fluorescence recovery after photobleaching

The total reduction power of algae extracts was determined using the Oyaizu method (Oyaizu, 1986). 2.5 mL phosphate (KH_2PO_4) buffer (0.2 M pH: 6.6) and 2.5 mL potassium ferricyanide $K_3Fe(CN)_6$ (1%) solutions were added to the tubes after pipetting Algae extracts and standards in different concentrations. Butylated hydroxytoluene (BHT) and butylated hydroxyanisol (BHA) were used as standard. After being thoroughly vortexed, it was incubated in a 50°C water bath for 20 minutes. Then, 2.5mL of 10% trichloroacetic acid (TCA) solution was added to this mixture and centrifuged at 3000 rpm for 10 minutes. After taking 2.5 mL of the centrifuged mixture and adding 0.5 mL of 1% iron (III) chloride ($FeCl_3$) solution to it and vortexing, their absorbance against void was read at 700 nm using UV-Vis spectroscopy.

Determination of ABTS cation radical removal activity (ABTS-2,2´-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)

ABTS is based on the inhibition of the absorbance of the radical cation by antioxidants. The Cation Radical (ABTS) Removal Activity was performed according to the method proposed by Re et al. (1999). 0.1 M pH: 7.4 PO_4^{3-} buffer, 2 mM ABTS and 2.45 mM potassium persulfate ($K_2S_2O_8$) solution were prepared for free radical (ABTS) removal activity. $ABTS^{\cdot+}$ and $K_2S_2O_8$ solutions (1:2) were mixed to become $ABTS^{+}$ - $K_2S_2O_8$ and incubated in the dark for 6 hours. At different concentrations (2,5-5-10 µg/mL) samples and standard solutions were taken and 1 ml of $ABTS^{\cdot+}$ - $K_2S_2O_8$ solution was added to it. A phosphate buffer was added so that the total volume was 4 ml. The mixture was vortexed and incubated for 30 minutes and spectrophotometric measurement was performed at 734 nm under room conditions. The decreased absorbance gives the amount of ABTS radicals removed from the environment. As standard, 6-hydroxy-2,5,7,8-tetramethyl chroman-2-carboxylic acid (Trolox), Butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) was used (Re et al., 1999).

Determination of fatty acid composition

In order to determine fatty acids, dried algae samples were crushed into powder by crushing in a press and 1 gram of each sample was used.

To determine fatty acids, saponification, methylation and extraction processes were performed. Fatty acids in algal species were determined using a gas chromatography (GC) method.

Gas chromatography analyzes were performed with HP (Hewlett Packard) Agilent brand gas chromatography with FID (Flame Ionization Detector: Flame ionization detector) detector and automatic injector. Capillary column was used and the injector block temperature was set to 210˚C and the detector temperature to 230˚C. The temperature program was applied to the column and the initial temperature of the column was set as 120˚C. Afterwards, it reached 185˚C with an increase of 4˚C per minute, and then 230˚C with an increase of 1˚C per minute. It was kept at this temperature for 5 minutes. Gas flow rates were adjusted as 30 ml min-1 for hydrogen, 300 ml min-1 for dry air and 1 ml min-1 for helium used as carrier gas, respectively (IUPAC, 1979).

Vitamin analysis

The algae samples were extracted with hexane: chloroform (3:1) after taking out of the deep freezer for study in HPLC. Then, the solvent was removed under vacuum and injected into the C18 column (150x4.6 mm ID, 5µm Wakosil) and the column temperature was kept constant at 50°C. Acetonitrile: methanol (1:1) was used as the mobile phase. The flow rate was programmed as 1ml/minute and a DAD detector was used as the detector. Calibration graphs were drawn using α-tocopherol and β-carotene as standard and vitamin amounts were calculated (Moreno and Salvadó, 2000).

Statistical analysis

All studies were performed in three repetition-format and the mean (±) was given as standard deviation (SD). Statistical analyses were performed using Microsoft Excel.

RESULTS

Results regarding antioxidant activity

According to the data obtained from the analysis of diphenyl-1-picrylhydrazyl (DPPH) free radical removal activity, the free radical removal activity of *Spirogyra daedaleoides* was measured as 17.56±0.45 µg (extract)/mL. The free radical removal activities of algal extracts were compared with the standards of Trolox, BHA and BHT (Table1).

The iron (III) ion reduction power (FRAP) activity of *Spirogyra daedaleoides* was measured as 2.65±0.35 µmol/mg (extract) in the results of the analysis. The free radical removal activities of algal extracts were compared with the standards of BHA and BHT (Table1).

According to the obtained data regarding the cation radical removal activity (ABTS), *Spirogyra daedaleoides* was measured as 8.89±0.37 µg (extract)/mL in the analyses. The free radical removal activities of algal extracts were compared with the standards of Trolox, BHA and BHT (Table1).

Table 1. Results of antioxidant analysis of *Spirogyra daedaleoides* extract

Antioxidant activity	DPPH µg/mL	FRAP µmol/mg	ABTS µg/mL
Spirogyra daedaleoides	17.56 ±0.45	2.65±0.35	8.89±0.37
BHA	5.78 ±0.23	4.35±0.18	5.48±0.12
BHT	7.67 ±0.21	3.87±0.17	6.89±0.18
Trolox	5.68 ±0.24	-	5.38±0.06

DPPH-Free Radical Removal Activity
FRAP-Iron (III) Ion Reduction Power Activity
ABTS-Cation Radical Removal Activity

Fatty acids

In the fatty acid analyses of *Spirogyra daedaleoides*, the ratios of C20:0 arachidic acid, C16:0 palmitic acid, C18:3n3 alpha-linoleic acid, C10:0 caprinic acid and C18:2n6c linoleic acid were found to be higher than the others, respectively, when ranked according to their % densities (Table 2).

Table 2. Fatty acid ratios of *Spirogyra daedaleoides* extract

Fatty acids	Value (%)
C10:0 Caprinic acid	**10.80**
C12:0 Lauric acid	3.93
C14:0 Myristic acid	1.00
C14:1 Myristoleic acid	0.06
C15:0 Pentadecanoic acid	0.06
C16:0 Palmitic acid	**18.76**
C16:1 Palmitoleic acid	1.83
C17:0 Heptadecanoic acid	0.37
C18:0 Stearic acid	2.52
C18:1 n9c Oleic acid	2.73
C18:2n6t Linolelaidic acid	0.16
C18:2n6c Linoleic acid	**5.23**
C18:3n6 gama Linoleic acid	1.36
C20:0 Arachidic acid	**25.78**
C18:3n3 alfa Linoleic acid	**18.01**
C20:2 cis11,14-eicosadienoic acid	0.17
C20:3n6 Dihomo-gamma-linolenic acid	1.20
C22:0 Behenic acid	0.31
C22:1n9 Erucic acid	0.38
C20:3n3 Eicosatrienoic acid	0.14
C20:5n3 Eicosapentaenoic acid	2.72
C24:0 Lignoceric acid	1.89
C24:1 Nervonic acid	0.13
C22:6n3 Docosahexaenoic acid	0.48

Vitamins

In the vitamin analyses of *Spirogyra daedaleoides*, the ratios of vitamins C, E and A were examined. According to the data obtained; vitamin C of *Spirogyra daedaleoides* was found to be 21.74 mg/kg, vitamin E was found to be 24.78 mg/kg and vitamin A was found to be 475.16 mg/kg and the results are given in Figure 1.

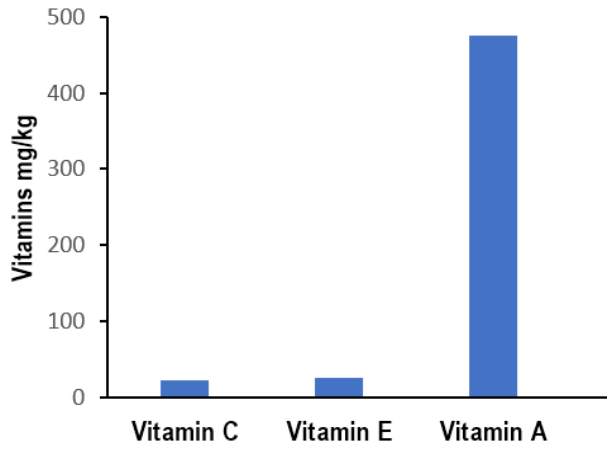

Figure 1. Vitamin C, E, A values of *Spirogyra daedaleoides* extract

DISCUSSION

Algae accumulate specific secondary metabolites, which are valuable products (such as pigments and vitamins) that are used in the cosmetics, food or pharmaceutical industry. In the environment in which they are growing, algae can be subjected to stress and extreme conditions such as changes in salinity, temperature or nutrient levels. To survive, these organisms must adapt to the new environment conditions and thus produce a large number of biologically active secondary metabolites that are not found in any other organism (Demorais et al., 2015).

Algae, which are very rich in nutritional value content, are also used in the health sector. *Spirulina*, a blue-green alga which is rich in protein content, has become a health-promoting food worldwide. It has been recognized as a rich source of protein, vitamins and minerals. While the protein content of Spirulina varies from 50 % to 70 % in its dried weight, the best source of vegetable protein is half that level (Kapoor and Mehta, 1993).

There are many different uses for algae today. Animal feed, vegetable fertilizer, water treatment process, dyes and additives used in food production are the prominent ones among these areas. It has also become an important part of nutrition in recent years. Algae are an important producer link of the food chain. Generally, their use as a food source in Southeast Asian and island countries is increasing the popularity of algae day by day (Ünver Alçay et al., 2017).

Antioxidants are molecules that are used to inhibit or prevent oxidation in living organisms. These molecules can eliminate free radicals. Thus, it delays lipid peroxidation as well as the progression of many chronic diseases (Gülçin, 2012).

According to the antioxidant analysis results of *Spirogyra daedaleoides*, free radical removal activity (DPPH) was found to be 17.56 ±0.45 µg (extract)/mL, iron (III) ion reduction power activity (FRAP) was found to be 2.65±0.35 µmol/mg (extract) and cation radical removal activity (ABTS) was found to be 8.89±0.37 µg (extract)/mL (Table 1).

In the study conducted with *Spirogyra porticalis* (Muell.) Cleve, water, methanol, acetonitrile and n-hexane were used as solvents. Antioxidant activity was determined by ferric reducing antioxidant power (FRAP), ABTS radical scavenging activity, 1,1-diphenyl-2-picrylhydrazyl radical (DPPH), β-carotene-linoleic acid bleaching, Nitric oxide (NO) scavenging and lipid peroxidation methods. They noted that methanol extracts had the highest antioxidant activity (Kumar et al., 2015). In this study, antioxidant activity was analyzed with the DPPH, FRAP and ABTS methods using methanol for extraction. The antioxidant activity of *Spirogyra daedaleoides* extracts was found to be high in all three methods.

In the study investigating the antioxidant properties of *Spirogyra neglecta* (Hassall) Kützing species), as a result of the analysis, the DPPH activity of *Spirogyra neglecta* was found to be 48.67 ± 3.06 µg/ml (Thumvijit et al. (2013). In this study, the free radical removal activity (DPPH) of *Spirogyra daedaleoides* was found to be 17.56 ± 0.45 µg (extract)/mL. The result obtained with the free radical removal activity (DPPH) analysis of *Spirogyra daedaleoides* is more effective than the results in the study of Thumvijit et al. (2013).

The fat content of algal species varies between 1-5%. Nevertheless, it contains much more essential fatty acids than other land plants. Due to their role as building blocks for fats in the organism and as building blocks for cell membranes, fatty acids play an important role in human and animal nutrition (Demirel and Özpınar, 2003).

In the fatty acid analysis of *Spirogyra daedaleoides*, it was found to have contained many types of fatty acids. Among them, C10:0 caprinic acid with 10.80%, C16:0 palmitic acid with 18.76%, C18:2n6c linoleic acid with 5.23%, C20:0 arachidic acid with 25.78%, C18:3n3 alpha linoleic acid with 18.01% were found to be higher than the others (Table 2).

In the study investigating the fatty acids of *Spirogyra* species, their fatty acid ratios were determined. C10:0 caprinic acid was 0.05-0.10%, C16:0 palmitic acid was 21.25-20.78%, C18:2n6c linoleic acid was 5.17-5.99%, C20:0 arachidic acid was 0.60-0.51%, C18:3n3 alpha linoleic acid was 0.10-0.09% in the study conducted with *Spirogyra* species (Erkaya and Yalcin, 2021). In this study, C20:0 arachidic acid, C16:0 palmitic acid, C18:3n3 alpha-linoleic acid fatty acid varieties were found to be at a higher rate.

Algae have critical functions in the energy cycle of the ecosystem. Algal biomass is used in the extraction of phycocolloids (alginate, carrageen and agar), as a source of pharmaceutical substances and as a food additive in different regions of the world (Ramaraj et al., 2014).

In the vitamin analysis of *Spirogyra daedaleoides*, vitamin C was found to be 21.74 mg/kg, vitamin E was found to be 24.78 mg/kg, vitamin A was found to be 475.16 (Figure 1).

Aaronson et al. (1977) researched *Chlamydomonas reinhardii*, *Chlorella vulgaris*, *Scenedesmus obliquus*, *Anabaena cyclindrica* and determined the amounts of Vitamin

A-E-C in their study. Vitamin A was found to be 105 ng in the *Chlamydomonas reinhardii*, vitamin E was 4 µg in the *Anabaena cyclindrica*, and vitamin C was 15 µg in the *Chlorella vulgaris*. In the study, it was determined that vitamins A and E were higher in the *Spirogyra daedaleoides*.

Ulva rigida, Gracilaria gracilis, Sargassum vulgare, Cystoseira barbata and Dictyopteris membranacea species were used in the study investigating the vitamin values of algae species. The results of vitamin analysis revealed that algae are rich in β-carotene (provitamin A), ascorbic acid (vitamin C) and α-tocopherol (vitamin E). The richest in β-carotene (provitamin A) is *Gracilaria gracilis with* 3.25 ± 0.41 mg while *Ulva rigida* was found to be the richest in vitamin C (ascorbic acid) with an amount of 17.42 ± 0.67 mg.100 g-1 *Dictyopteris membranacea* was found to be the richest in the tocopherol (vitamin E) with an amount of 5.03 ± 0.12 mg.100 g-1(Turan and Cirik, 2018). In this study, the Vitamin A, E and C levels of *Spirogyra daedaleoides* were investigated and higher values were found in all three vitamins. With these characteristics, the species have the characteristics to be used as a natural resource in the food industry.

CONCLUSIONS

Algae are naturally rich sources of biologically active compounds such as antibiotics, antivirals, anticancer and antioxidants. In addition, these microorganisms can improve health and reduce the risk of developing degenerative diseases. In the development of new pharmaceutical substances, the research of these biologically active compounds is of great importance to ensure chemical and pharmacological innovation and diversity.

Considering the positive results regarding the antioxidant, fatty acid and vitamin contents of *Spirogyra daedaleoides* used in the research, it is planned to isolate the active substances and contribute the information to the literature in future studies.

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CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest on this manuscript.

ETHICAL APPROVAL

Ethical approval is not required for this study.

DATA AVAILABILITY

All relevant data is inside the article.

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ARAŞTIRMA MAKALESİ RESEARCH ARTICLE

Seriola dumerili (Risso, 1810) ve *Lichia amia* (Linnaeus, 1758) türlerine ait Türkçe isimlerin genel ve yerel kullanımlarının değerlendirilmesi

Evaluation of general and local usage of Turkish names of *Seriola dumerili* (Risso, 1810) and *Lichia amia* (Linnaeus, 1758) species

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Öz: Bu çalışmada *Seriola dumerili* ve *Lichia amia*'nın bölgelere göre kullanılan yerel isimleri, Ege ve Akdeniz'e kıyısı olan 10 il ve 11 istasyonda balıkçılarla ve konunun paydaşlarından olan amatör balıkçıların türkçe isim kullanımları sosyal medya aracılığı ile değerlendirilmiştir. Arazi çalışmalarının sonuçlarına göre balıkçıların kıyı illerimizde ağırlıklı olarak *S. dumerili*'yi %89 akya olarak adlandırdığı tespit edilmiş, ayrıca %5 kuzu, %3 avcı ve %3 imtiyaz isimlerinin kullanıldığı görülmüştür. *L. amia*'nın %73 çıplak olarak adlandırıldığı %15 akya fulya, %9 çatal kuyruk ve %3 liça olarak kullanıldığı görülmüştür. Amatör balıkçılar kıyı illerimizde *S. dumerili* için %54 kuzu, %37 akya ve %9 sarı kuyruk isimlerini kullanmaktadırlar. *L. amia* için sırası ile %45 liça, %28 çatal kuyruk ve %15 akya, %11 çıplak ve %1 akya fulya amatör balıkçılar tarafından kullanılan isimler olmuştur. Ayrıca makale, kitap, teknik rapor gibi basılı kaynaklarda kronolojik sıra gözetilerek konu incelenmiş ve *L. amia* için akya, *S. dumerili* için sarı kuyruk kullanıldığı görülmüştür. Geçmişten günümüze, hatalı kullanımların olmaması ve isim birliği için balıkları isimlendiren balıkçıların *S. dumerili* için kullandıkları akya ile *L. amia*'nın çıplak, olarak kullanımları doğru olacaktır.

Anahtar kelimeler: Yerel balık isimleri, akya, çıplak

Abstract: In this study, the local names of *Seriola dumerili* and *Lichia amia* were evaluated by the use of Turkish names by fishermen in 10 provinces and 11 stations on the Aegean and Mediterranean coasts, and amateur fishermen, who are stakeholders in the subject, were evaluated through social media. In addition, the subject was examined in chronological order in printed sources. According to the results of the field studies, it was determined that 89% of all fishermen named *S. dumerili* as akya, mainly in our coastal provinces. It has been observed that 5% is used as kuzu, 3% as avcı and 3% as imtiyaz. It has been determined that *L. amia* is called 73% çıplak. It has been observed that 15% is used as akya fulya, 9% as çatal kuyruk and 3% as liça. The names amateur fishermen use for *S. dumerili* in our coastal provinces are 54% kuzu, 37% akya and 9% sarı kuyruk. For *L. amia*, the names used by amateur fishermen were 45% liça, 28% çatal kuyruk, 15% liça, 11% çıplak and 1% akya fulya, respectively. In written sources such as articles, books and technical reports, it has been seen that they use akya for *L. amia* and sarı kuyruk for *S. dumerili*. From past to present, it would be correct to use *L. amia* as çıplak and *S. dumerili* as akya, which fishermen have used to avoid incorrect usage and have unity of name.

Keywords: Common fish names, greater amberjack, leerfish

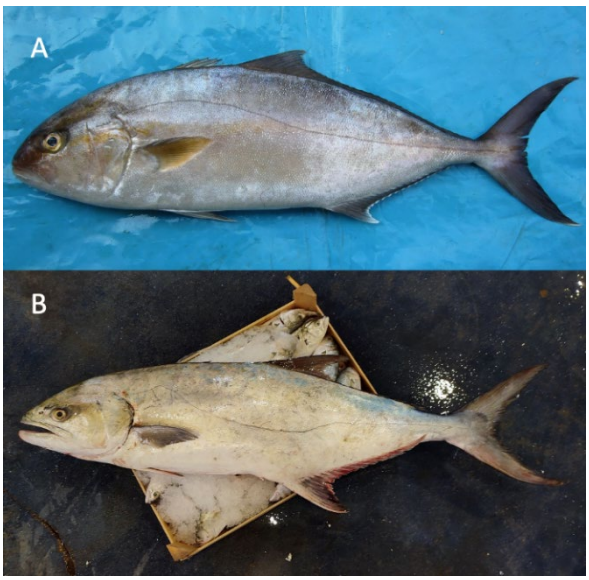
GİRİŞ

Carangidae familyası, dünya okyanus ve denizlerinde ılıman ve sıcak kuşakta dağılım gösteren bir familya olup irili ufaklı çok sayıda türü içermektedir. Bu grup üyelerinin birçoğu, iyi bilinen bir tür olan istavrit gibi ticari değere sahiptir. *Seriola* ve *Lichia* cinsinin de içinde bulunduğu Carangidae familyası Akdeniz'de 21 tür ile temsil edilirken (Kovacic vd., 2021), ülkemiz sularında 16 türü vardır (Bilecenoğlu vd., 2014). *Seriola* cinsinin dünya denizlerinde 10 türü, Akdenizde ise: *Seriola dumerili* (Risso, 1810), *Seriola carpenteri* Mather, 1971, *Seriola fasciata* (Bloch, 1793), *Seriola rivoliana* Valenciennes, 1833 olmak üzere 4 türü bulunmaktadır. *S. dumerili* dışında kalan üç tür 2000 yılından sonra Akdeniz faunasına dahil olan tropik Atlantik kökenli türlerdir. Bununla birlikte *Lichia* cinsi dünya genelinde tek bir tür, *Lichia amia* (Linnaeus, 1758) ile temsil edilmektedir. Bu çalışmaya konu olan *S. dumerili* ve *L. amia* ekosistem için değerli olmalarının yanında ticari açıdan da önem taşıyan türlerdir. *S. dumerili* denizlerimizde, Ege ve Akdeniz de dağılım gösterirken, *L. amia*'nın dört denizimizde de kaydı bulunmaktadır. *Seriola* cinsi ülkemizde 2 tür ile temsil edilir. *Seriola* genusunun ikinci türü olan *Seriola fasciata* türü ülkemizin güney Ege ve Akdeniz kıyılarında nadiren karşılaşılıp yerel bir isim ile anılmadığı için bu çalışmada yer verilmemiştir.

Tüm tropikal ve ılıman okyanus ile denizlerde 385 metre derinliğe kadar dağılım gösteren *S. dumerili*, 2 m boya kadar ulaşabilen büyük bir balıktır. Gövde yapısı füze şeklindedir, 2 dorsal yüzgeci vardır. Birinci dorsal kısa olup 8 adet diken ışın içermektedir. İkinci dorsal yüzgeç birincinin bitiminden başlayıp kuyruk sapına kadar uzamakta ve 29-35 adet yumuşak ışın içermektedir. Anal yüzgeç tek olup 2. dorsal yüzgeç izdüşümünün biraz gerisinden başlayıp aynı hizada biter. 3 adet diken, 18-22 adet yumuşak ışın bulunmaktadır. Pektoral yüzgeç kısa olup, pelvik yüzgeç, pektoral yüzgeç başlangıç noktası izdüşümünün biraz gerisinde yer almaktadır. Kuyruk yüzgeci oldukça gelişmiş olup hilale yakın bir şekle sahiptir. Ağız geniş olup alt ve üst çenede avlarını tutmaya yarayan çok

sıralı küçük dişlere sahiptir. Yanal çizgi operkulumun arkasından başlayıp bir yay çizerek gövdenin ortasına iner ve kuyruk boyunca devam eder. Gövde üzerinde küçük sikloit pullara sahiptir (Froese ve Pauly, 2024). Renk balık canlıyken gövde boyunca sırtta pembemsi gri gümüş yanlarda ve karında gümüşi beyazdır. Ölü balıklarda başın üstü ve sırt kısmı matlaşarak soluk gri-boz renge döner. Balık canlı iken üst çeneden başlayıp gözlerin üzerinden başın arkasına doğru, sürme benzeri kahverengi bir şerit vardır. Vücudun iki yanında gözün arkasından kuyruk sapına kadar uzanan sarımtırak bir şerit bulunmaktadır. Bu şerit balık canlı ve taze iken daha belirgin olup balık öldüğünde solmaktadır. (Şekil 1. A).

L. amia Doğu Atlantik'te Biscay körfezinden Güney Afrika'nın doğu sahillerine kadar ve Akdenizde dağılım göstermektedir. 2 m'ye yaklaşan boyu ile hemen hemen aynı büyüklüğe ulaşan *S. dumerili*'ye göre gövdesi daha yüksek ve yanlardan daha basıktır. Ağız geniş olup alt ve üst çenede avlarını tutmaya yarayan çok sıralı küçük dişlere sahiptir. 2 dorsal yüzgeci vardır. Birinci dorsal geriye yatık çok sert ve kısa 7 adet diken ışın içermektedir. İkinci dorsal yüzgeç birincinin bitiminden başlayıp kuyruk sapına kadar uzanmakta ve 1 diken, 19-21 adet yumuşak ışın içermektedir. Anal yüzgeç 2. dorsal yüzgecin tam hizasında yer almakta, 2 bağımsız diken ışın ve 1 diken, 17-21 adet yumuşak ışın bulunmaktadır. Pektoral yüzgeç kısa olup, pelvik yüzgeç pektoralin altında konumlanmaktadır. Yanal çizgi *Seriola*'dan farklı olarak sırttan karına kavis yaparak iner sonra yükselerek kuyruk boyunca devam edip kuyruk yüzgeci ile sonlanır. Gövdede yer alan oldukça küçük pullar, deriye iyice yapışmış olup balığa pulsuz bir balık görünümü vermektedir. Renk sırtta kurşuni griden yeşil ve maviye değişmektedir. Yanları gümüşi beyaz olup karın kısmı beyazdır. Balığın dorsal ve anal yüzgeç uçları siyahtır (Froese and Pauly, 2024). (Şekil 1. B).



Şekil 1. A: *Seriola dumerili* (Risso, 1810) Foto: Erhan Irmak
B: *Lichia amia* (Linnaeus, 1758) Foto: Erhan Irmak

Figure 1. A: *Seriola dumerili* (Risso, 1810) Photo: Erhan Irmak
B: *Lichia amia* (Linnaeus, 1758) Photo: Erhan Irmak

Büyük pelajik türlerden olan bu balıklar, balıkçılığımızın hedef türlerinden ikisini oluşturmaktadır. Bu nedenle gırgır, alamana vb. çevirme ağları ile olta takımları gibi av araçları ile yaygın olarak avlanmaktadır. Bunun yanı sıra, uzatma ağı, paragat, yemli sürütme takımı, sırtı takımı, bırakma oltası gibi türe özel çeşitli av araç ve yöntemleri bulunmaktadır (Tokaç vd., 2010). Bu türlerin su ürünleri istatistiklerinde adı geçmekte ve balık avcılığını düzenleyen tebliğlerde, avcılığının düzenlenmesi ve korunmasına yönelik ilgili maddelerde yer almaktadır (TÜİK, 2004- 2021; TKB, 2006).

Seriola spp. et kalitesi ve hızlı büyüyen büyük balıklar olması sebebi ile kültür balıkçılığının da hedef türlerinden biri olmuştur. Bu kapsamda 1960'lardan bu yana Japonya'da *Seriola quinqueradiata* Temminck & Schegel, 1844, ve *S. dumerili* üretimi yapılmaktadır. Üretim miktarı 2014'te 150.387 ton/yıl gibi rakamlara ulaşmıştır. *Seriola lalandi* Valenciennes, 1833 ise diğer üretilen önemli bir türdür (Sicuro ve Luzzana, 2016).

Balıklar isimlendirilirken isim türetmesi, hayvan ve bitki adları, fiziksel özellikleri ve renk gibi durumlardan faydalanılmaktadır. Bunun yanında yabancı dilden gelen kelimelerin Türkçe'nin bilim diline yerleşmesine yardımcı olmaktadır. Balıkçıların kullandıkları isimler, coğrafyadan kaynaklı algıların farklı olmasından dolayı yöresel olarak farklılık gösterebilmektedir (Uysal, 2011). Balıklar, yerel isimlerinin bir kısmını Yunanca'dan almış olup, bir kısmı ise şekil, renk, özellik, yaşadıkları yer, hayvan eşya isimleri ve keyfi olarak isimlendirilmişlerdir (Caferoğlu, 1960). Ticari balık isimleri, balıkçıların balıkları pazarlarken başka türler ile karışmaması için önem taşımaktadır. Hayatlarının önemli bir kısmını denizde geçiren balıkçılar yakaladıkları balıkları kısaca tarif eden isimler kullanmaktadırlar.

Ülkemizin Ege ve Akdeniz kıyılarında dağılım gösteren *S. dumerili*'nin basılı kaynak ve günlük konuşma dilinde kullanılan, sarı kuyruk, avcı, imtiyaz, akya ve kuzu balığı gibi Türkçe ve yerel isimlere sahiptir. Dört denizimizde de dağılım gösteren *L. amia*'nın literatürde yaygın olarak kullanılan Türkçe isimlerinin, akya, çıplak, liça, leka ve çatal kuyruk olarak verildiği görülmektedir (Mater vd., 2003; Akşıray, 1987). Türlerin birden fazla Türkçe isimlerinin oluşu ve ortak kullanılan isimlerin olması da hem sözlü hem de yazılı kullanımlarında karışıklıklara yol açmaktadır. Makale, kitap, teknik rapor, su ürünleri istatistik verileri ve denizlerde avcılığı düzenleyen kuralların yer aldığı sirküler ile tebliğler gibi yazılı metinler ile amatör balıkçıların ve balıkçıların akya adı altında 2 farklı türü ifade etmeleri sorunun ana kaynağını oluşturmaktadır.

Bahse konu olan balık isimleri hem basılı kaynaklarda hem de günlük kullanımda sıklıkla karıştırılmaktadır. Bu karışıklığı ortadan kaldırabilmek amacıyla yerel isim kullanımları da dikkate alınarak isim kargaşasının giderilmesi ve doğru kullanımının yaygınlaştırılması amaçlanmıştır.

MATERYAL VE METOT

Bu çalışma 2005-2024 yılları arasında yürütülmüştür. İlgili türlerin optimum koşullarda dağılım gösterdiği dolayısı ile

sosyo-ekonomik değer taşıdığı Ege ve Akdeniz bölgelerinde 10 kıyı ilimizde Enez, Çanakkale, Ayvalık, Güzelbahçe, Kuşadası, Fethiye, Antalya, Alanya, Taşucu, Karataş ve Çevlik balıkçı limanlarında balıkçılık ile geçinen kişiler (balığı tutan, komisyoncu, satan ve nakil eden) ile her ilde en az 10 en çok 60 kişi ile birebir görüşmeler yapılmıştır. Balıkçı limanlarının yanında var ise balık mezatları, balık halleri ve balık satış noktalarından faydalanılmıştır. Bu kapsamda *S. dumerili* ve *L. amia*'nın renkli basılı fotoğrafı kullanılarak tek tek balıkların Türkçe veya yerel/yöresel isimleri sorulmuştur ve balığa birden fazla isim verilmesi durumunda ilk söyledikleri isim dikkate alınmıştır. Balıkçıların av bölgeleri dikkate alınarak illere göre kullanılan balık isimleri değerlendirilmiştir.

Konunun diğer bir paydaş gurubunu oluşturan amatör balıkçıların iki tür için kullandıkları isimler internet ortamında, çalışmaya konu olan balıkların avcılık videolarının yer aldığı ve erişimin serbest olduğu '*Youtube'* sosyal medya platformunda taranmıştır. Hedef grup olan amatör balıkçıların iki tür ile ilgili kullandıkları isimler seçilmiştir. Anahtar kelime olarak; akya, liça, çıplak, çatal kuyruk, akya fulya, kuzu, sarı kuyruk, avcı ve imtiyaz kelimeleri girilerek tarama yapılmıştır. 810 adet video 30 saat 20 dakika boyunca izlenerek her bir tür için 150 adet olmak üzere toplamda 300 adet video içeriği değerlendirilmiştir. Tekerrüre düşmemek adına aynı kişilerin olmamasına dikkat edilmiştir. Ayrıca video başlığında geçen balık adları dikkate alınmayıp video içeriklerindeki söz ile ifade edilen balığın adı değerlendirilmiştir. Video için atılan başlıklar sadece tek isim kullanılması ve video içeriğinde balığı adının geçmemesi durumunda dikkate alınmıştır. Ayrıca video ve görsel içerikleri üreten amatör avcıların av bölgeleri dikkate alınarak illere göre kullanılan Türkçe ve yerel isimleri değerlendirilmiştir.

Çalışmaya konu balıkların isimlerinin geçtiği, kaynak olarak kullanılan kitap, teknik rapor, makale, tebliğ ve su ürünleri istatistiği gibi yazılı metinler geçmişten günümüze değerlendirilmiştir. Makale, kitap ve teknik raporlarda bahsi geçen türün netlik kazanması adına, bilimsel isimleri ve Türkçe adları birlikte kullanılan kaynaklar değerlendirilmiştir.

BULGULAR

Çalışma bölgesi olarak *S. dumerili* ve *L. amia* 'nın optimum koşullarda dağılım gösterdiği Ege ve Akdeniz'e kıyısı olan 10 ilde 11 istasyon seçilmiştir. Enez (15), Çanakkale (20), Ayvalık (16), Güzelbahçe (60), Kuşadası (24), Fethiye (52), Antalya (18), Alanya (14), Taşucu (32), Karataş (30) ve Çevlik (10) limanlarında olmak üzere toplam 291 balıkçı ile görüşülmüştür ve *S. dumerili* ile *L. amia*' nın Türkçe yerel isimleri belirlenmiştir.

Seriola dumerili (Risso, 1810)

Balıkçılar ile yapılan görüşmeler sonucunda fotoğraf üzerinden balıklar tayin edilmiş olup 6 il ve 6 istasyonda Enez (15), Çanakkale (20), Ayvalık (16), Güzelbahçe (60), Kuşadası (24), Fethiye (52) *S. dumerili* için %100 akya isminin kullanıldığı tespit edilmiştir. Bunun yanında balıkçıların Antalya'da %56 kuzu balığı (10) ve %44 akya (8), Alanya'da %64 akya (9), %36 kuzu balığı (5), Taşucu'nda %81 akya (26), %19 avcı (6), Adana Karataş'ta %74 akya (22), %20 imtiyaz (6) ve %6 avcı (2), Çevlik'te %80 akya (8) ve % 20 imtiyaz (2) adının kullanıldığı tespit edilmiştir. Bununla birlikte arazi çalışmalarının sonuçlarına göre balıkçıların kıyı illerimizde ağırlıklı olarak *S. dumerili*'yi %89 akya (260) olarak adlandırıldığı tespit edilmiştir. %5 kuzu (15), %3 avcı (8) ve %3 imtiyaz (8) isminin yerel olarak kullanıldığı görülmüştür.

İnternet ortamında, çalışmaya konu olan balıkların avcılık videolarının ve görsellerinin yer aldığı sosyal medya kaynakları taranarak, hedef grup olarak amatör balıkçıların iki tür ile ilgili kullandıkları isimler şu şekilde tespit edilmiştir: *S. dumerili* için izlenen 150 videonun illere göre dağılımı dikkate alındığında en fazla değerlendirilmeye alınan şehir %47 ile Antalya (71) olmuştur. Antalya'yı sırası ile %15 Hatay (22), %13 Muğla (19), %11 Mersin (17), %9 Adana (14), %3 İzmir (4), %1 Çanakkale (2), %1 Aydın (1) izlemiştir. İllere göre tercihlere bakacak olursak: kuzu balığı adı, %65 Antalya (52)'da kullanılmış olup, sırası ile %14 Mersin (11), %7 Hatay ve Muğla (6), %4 Adana (3), %2 İzmir (2), %1 Aydın (1) kez takip etmiştir. Akya ismi en çok kullanılan 2. isim olurken illere göre dağılımı: %34 Antalya (19), %23 Hatay ve Muğla (13), %7 Mersin (4), %4 Adana, İzmir ve Çanakkale (2), %1 Aydın (1) şeklinde olmuştur. Sarı kuyruk adının illere göre dağılımı şu şekilde olmuştur: %65 Adana (9), %21 Hatay (3), %14 Mersin (2) kez kullanmıştır. Sonuçlara göre tüm amatör balıkçıların kıyı illerimizde sırası ile %54 kuzu (80), %37 akya (56) ve %9 sarı kuyruk (14) kullandıkları isimler olmuştur.

Lichia amia (Linnaeus, 1758)

Yapılan görüşmeler sonucunda balıkları tutan balıkçıların, komisyoncuların, balık satıcılarının ve balıkları nakil eden kişilerin tamamının fotoğraftan tayin edilen balık türü için, Edirne Muğla arasında 5 il ve 5 istasyonda (Enez, Çanakkale, Ayvalık, Güzelbahçe, Kuşadası) *L. amia* %100 çıplak isminin kullanıldığı tespit edilmiştir. Muğla ili Fethiye'de 52 balıkçının %83 akya fulya (43), %13 çıplak (7) ve %4 liça (2) ismini kullandıkları, Antalya'da %72 çıplak (13) ve %28 liça (5), Alanya'da %86 çıplak (12), %14 çatal kuyruk (2), Taşucu'nda %69 çıplak (22), %25 çatal kuyruk (8), %6 liça (2), Adana Karataş'ta %67 çıplak (20) ve %33 çatal kuyruk (10), Hatay Çevlik'de %60 çatal kuyruk (6) ve %40 çıplak (4) adının kullanıldığı belirlenmiştir. Bunun yanı sıra arazi çalışmalarının sonuçlara göre tüm balıkçıların kıyı illerimizde ağırlıklı olarak *L. amia*'nın %73 çıplak (213) olarak adlandırıldığı tespit edilmiştir. %15 akya fulya (43), %9 çatal kuyruk (26) ve %3 liça (9) isminin yerel olarak kullanıldığı görülmüştür.

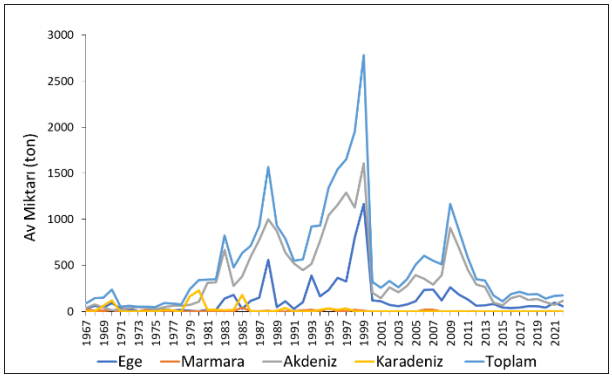
İnternet ortamında, çalışmaya konu olan balıkların avcılık videolarının ve görsellerinin yer aldığı sosyal medya kaynakları taranarak, hedef gurup olarak amatör balıkçıların *L. amia* için kullandıkları isimler şu şekilde tespit edilmiştir: İzlenen 150 video'nun illere göre dağılımında en fazla değerlendirilmeye alınan il %25 ile Hatay (37) olmuştur. Hatay'ı takiben sırası ile %19 Antalya (29), %15 Mersin (23), %15 Adana ve Muğla (22), %4 Aydın (6), %3 Çanakkale (5), %3 İzmir (4), ve %1 Edirne (2) olmuştur. İllere göre tercihlere bakılacak olursa: liça, %35

ile en fazla Antalya (25)'da kullanılmış olup, sırası ile %20 Muğla (14), %11 Mersin (8), %8 Hatay ve Adana (6), %7 Aydın (5), %6 Çanakkale (4), %4 İzmir (3) kez takip etmiştir. Çatal kuyruk ismi en çok kullanılan 2. İsim olurken illere göre dağılımı: %60 Hatay (24), %33 Adana (13), %10 Mersin (4), %3 Antalya (1) şeklinde olmuştur. Akya adının illere göre dağılımı şu şekilde olmuştur: %17 Hatay, Adana, Mersin ve Muğla (4), %10 Antalya ve Edirne (2), %4 Aydın, İzmir ve Çanakkale (1) kez kullanmıştır. Çıplak isminin kullanımı sırasıyla; %46 Mersin (7), %20 Hatay ve Muğla (3), %7 Adana ve Antalya (1) olmuştur. Akya fulya ismi sadece %100 Muğla için 1 kullanıma rastlanılmıştır. Çalışmalarının sonuçlara göre Sırası ile %45 liça (67), %28 çatal kuyruk (42) ve %15 akya (23), %11 çıplak (17) ve %1 akya fulya (1) amatör balıkçılar tarafından kullanılan isimler olmuştur. Basılı metinler incelendiğinde, bilimsel ve Türkçe adları birlikte verilen kaynak kitap, makale ve teknik raporlarda kullanılan isimler Tablo 1'de verildiği gibidir.

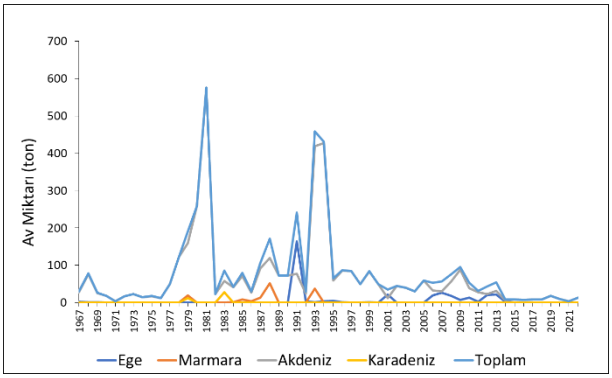
Tablo 1. Kaynak kitap ve makalelerde *L. amia* ve *S. dumerili*'nin Türkçe kullanılan isimleri
Table 1. Turkish names of *L. amia* and *S. dumerili* in published books and articles

Kaynak	*Lichia amia*	*Seriola dumerili*
Deveciyan (1926)	Akya, Beyaz balık	–
Akşıray (1954)	Akya, leka	–
Nalbandoğlu (1954)	Akya, leka	–
Kosswig ve Türkmen (1954)	Akya, leka	–
Slastenenko (1955)	Akya	–
Caferoğlu (1960)	Akya	Akya
Palombi ve Santarelli (1969)	–	Akya
Geldiay (1969)	Akya	Sarı kuyruk
Geldiay (1976)	Akya	Sarı kuyruk
Üner (1977)	Akya, leka, çıplak, kuzu	–
Atay (1985)	Çıplak, leka, kuzu balığı, iskender balığı	Sarı kuyruk
Akşıray (1987)	Akya, Leka, Çıplak	Sarı kuyruk, avcı
Mater vd. (1989)	Akya	Sarı kuyruk
Mater ve Meriç (1996)	Akya	Sarı kuyruk, avcı
Demirsoy (1997)	Akya, liça	Sarı kuyruk
Mater vd. (2003)	Akya	Sarı kuyruk, avcı
Alpbaz (2005)	–	Akdeniz sarı kuyruk balığı
Can ve Bilecenoğlu (2005)	Akya	Avcı, sarı kuyruk
Turan (2007)	Akya	Avcı, sarı kuyruk
Sarıeyyüpoğlu vd. (2009)	Akya	Sarı kuyruk
Tokaç vd. (2010)	Çıplak	Sarı kuyruk, akya
Tıraşın ve Ünlüoğlu (2012)	Akya, avcı	Sarı kuyruk, kuzu balığı

Su ürünleri istatistik verilerinin yer aldığı TÜİK su ürünleri istatistikleri 1967-2021 yılları değerlendirilmiştir. Bu istatistiklerde akya ve avcı olmak üzere iki farklı yerel isim karşımıza çıkmakta olup yıllık av verileri Şekil 2 ve Şekil 3'de verilmiştir. Akya'nın İngilizce karşılığı leerfish şeklinde belirtilmesinden *L. amia* olarak kayıt edildiği anlaşılmaktadır. Avcı için 2004 yılına kadar yöresel ürün olduğu ve İngilizce karşılığı bilinmiyor notu düşülmüştür. 2004 yılından sonra ise Avcının İngilizce karşılığı "Greater amberjack" olarak kabul gördüğü yani *S. dumerili* olarak kaydedildiği görülmektedir (DİE, 1967- 2003; TÜİK, 2004-2021). Denizlerde ve İç sularda Ticari ve Amatör Amaçlı Su Ürünleri Avcılığını Düzenleyen Sirküler ve Tebliğlerde akya, avcı ve sarı kuyruk olarak bu iki balığın adının geçtiği görülmektedir. 1997- 2004 arası dönemini kapsayan sirkülerde akya için *L. amia*, avcı için *S. dumerili* adı kullanılmıştır. 36/1 numaralı tebliğde 2004-2006 dönemi ile birlikte *L. amia* için akya adının kullanımı değişmezken, *S. dumerili* için avcı yerine sarı kuyruk adı kullanılmaya başlamıştır (TKB, 1997, 2004, 2006).



Şekil 2. Akya yıllık av verileri (DİE, 1967-2003; TUİK, 2004-2021)
Figure 2. Akya annual catch data (DİE, 1967-2003; TUİK, 2004-2021)



Şekil 3. Avcı yıllık av verileri (DİE, 1967-2003; TUİK, 2004-2021)
Figure 3. Avcı annual catch data (DİE, 1967-2003; TUİK, 2004-2021)

TARTIŞMA

Ülkemiz Ege ve Akdeniz kıyılarındaki balığı tutan, satan ve nakliyesini gerçekleştiren ticari balıkçılarımız tarafından *S. dumerili* ve *L. amia* için Türkçe ve yerel adları ile ilgili kendi ekosistemlerinde bir karışıklık görülmezken, konunun yazılı metinlerini oluşturan bilimsel makale ve kitaplarda ise balıkçılardan farklı Türkçe ve yerel isim kullanılmaktadır (Tablo 1). Diğer paydaş grup olan amatörler balıkçılarda isim birliği görülmemektedir.

Aynı şekilde devlet kurumlarına ait basılı yayınları olan su ürünleri istatistikleri ile sirküler ve tebliğlerde ortak bir Türkçe isim kullanılmadığı tespit edilmiştir (DİE, 1967- 2003; TÜİK, 2004-2021; TKB, 2006).

Balıklara isim verilirken şekil ve renk sık sık kullanılır. Balıklar bazen de diğer canlılara benzetilerek, benzetilen canlıların isimleri ile anılırlar. Akya, kullanımı çok eskiye giden Osmanlı döneminden günümüze ulaşan bir isimdir. Akya'nın yanında Deveciyan (1926)'da renk ifade eden "Beyaz balık" kullanılmıştır. Bunun yanında *S. dumerili* için Antalya ve civarında kuzu balığı adı yaygın olarak kullanılmaktadır. Kuzu benzetmesi iki farklı anlam ile yapılmaktadır. Bunlardan ilki, balığı bir başka canlıya benzetme yolu ile renk ve büyüklüğünü tasvir etmek için memeli bir hayvan olan koyun yavrusu kuzuya benzetilmektedir. İkincisi akya'nın genç bireylerini tanımlamak için kuzu ismi kullanılmaktadır. Yine Akdeniz bölgesinde Mersin ve Adana kıyılarında balıkçılar tarafından kabul gören avcı adı, balığın avcı özelliğini ortaya koyan bir isimdir. Mersin yöresinde balık hali istatistiklerinde akya ile avcı'nın aynı balık için kullanıldığı tespit edilmiştir (Akagündüz, 1965). Buna ek olarak Adana ve Hatay'da ise imtiyaz yerel ismi ile anıldığı belirlenmiştir. İmtiyaz köken olarak Arapçadan geldiği, Suriye ve İsrail de benzer olarak intias ismi kullanıldığı görülmektedir (Froese ve Pauly, 2024).

Balıkçılar ile amatör balıkçıların iki türün Türkçe isimlerinde tercihlerinin aynı olmadığı görülmektedir. *S. dumerili* türünün yaygın bir şekilde avlandığı Antalya kıyılarında, balıkçılar ile etkileşim halinde olan amatör balıkçılar ve balık meraklıları büyük çoğunlukla kuzu balığı ismini benimsemişlerdir. Amatör balıkçıların, internet kullanımının artması ve birbirlerini sosyal medya mecralarından sıkı takibi sonucunda *S. dumerili* için kuzu adının kullanımı oldukça yaygınlaşmıştır. İnternet ve medyada çıkan bu balıkla ilgili haberler yine kuzu balığı adının kullanımını yaygınlaştırmaktadır. Bununla birlikte literatüre sadık kalınarak, burada belirtildiği şekliyle sarı kuyruk *S. dumerili*'nin amatörler balıkçılar arasında kullandıkları diğer yaygın ismidir. Ancak bu ismin yalnızca Hatay, Adana ve Mersin ile sınırlı kalması, bölgedeki amatör balıkçıların birbirleri ile olan etkileşiminden kaynaklandığı düşünülmektedir. Aynı şekilde *S. dumerili* için akya ismi yaygın olarak kullanılsa da kuzuya nazaran daha az tercih edilmiştir.

L. amia'nın sahip olduğu beyaz renk tonlarının yanında, derisine iyice gömülmüş küçük pulların bu balığın adeta pulsuz bir balık görüntüsü vermesinden dolayı balıkçılar bu türe çıplak adını vermiştir. Bütün illerimizde balıkçılar tarafından kullanılan bir isim olmuştur. Liça veya Leka'nın türün cins adı olan *Lichia* 'dan köken aldığı anlaşılmaktadır. Bizde olduğu gibi bazı Akdeniz ülkeleri; Arnavutluk, Hırvatistan, Sırbistan, Slovenya ve Portekiz liça adını kullanmaktadır (Froese ve Pauly, 2024). Enez Muğla arasındaki istasyondaki balıkçılar tarafından çıplak öncelik görüp, liça değerlendirilmeye alınmadığı için liça'nın isimlendirmede oranı düşük çıkmıştır. Çatal kuyruk ise özellikle Mersin, Adana ve Hatay'ı içine alan Akdeniz kıyı ilerimizde kullanılan, oldukça gelişmiş hilale yakın kuyruk yapısının özelliği göz önüne alınarak verilen bir yerel isimdir. Akya fulya adı oldukça sınırlı bir kullanıma sahip olup sadece Fethiye'de kullanılmaktadır. Buradaki fulya kelimesinin geniş, yassı anlamı olan bir sıfat olduğu tespit edilmiştir.

Balıkçıların yaygın olarak çıplak kullanımına karşın amatör balıkçılar *L. amia* için liça adını kullanmaktadırlar. Bununla birlikte çatal kuyruk Hatay, Adana ve Mersin de kullanım gören diğer yerel isim olmuştur. Balıkçıların aksine Amatör balıkçıların ilgili kaynak kitapları takip etmeleri akya adını *L. amia ve S. dumerili* için ortak kullanmalarına yol açmıştır. Bunun sonucunda iki farklı balık için aynı adı kullanmak istemeyen amatör balıkçıların liça ismini tercih ettikleri görülmektedir. Amatör balıkçılarda yüksek oranda çıplak yerine liça ve çatal kuyruk kullanımının bir diğer sebebi bölgesel farklılıklardır. İzlenen videolarda ağırlıklı olarak Akdeniz'e kıyısı olan illerdeki av oranının % 89 olması yöresel isim olan çatal kuyruk kullanımını artırmaktadır.

Literatürde akya adının geçtiği en eski kaynak Deveciyan (1926) olarak görülmektedir ve *L. amia* için bu adı kullanmıştır. Bunu takiben *L. amia* için akya adını kullanan tüm araştırmacıların bu çalışmayı referans aldığı anlaşılmaktadır. Geldiay (1969)'da *S. dumerili* için ilk defa sarı kuyruk adının kullandığını görmekteyiz. Yerel isimlerin dikkate alınmayıp yabancı dillerden "Yellow tail" Türkçeye çevrilerek sarı kuyruk olarak devşirilmiş olduğu anlaşılmaktadır. Bundan sonra kullanılan tüm sarı kuyruk adları bu eser referans alınarak kullanıldığı tespit edilmiştir (Tablo 1).

Deveciyan (1926)'da akya'nın İstanbul balık haline yılda en fazla 40-50 adet olarak çoğunun Çanakkale'den getirildiğini söylemektedir. Çanakkale bölgesi iki türün yaşam alanı olup arazi çalışması sonucunda bölge balıkçılarının tamamının akya'yı *S. dumerili* için kullandıklarını düşünürsek muhtemelen İstanbul balıkçılarının balığı çok iyi tanımadığı için yanlış isimlendirilme olasılığı yüksektir. Üner (1977)'de Deveciyan, (1926)'da kullanılan balık çiziminin birebir kullanılması, bu eserin etkisi altında kalındığının bir göstergesidir. Bununla birlikte bu eserde akya'ya Akdeniz balıkçıları tarafından çıplak, leka ve kuzu balığı adının verildiğini söylemesi, akya adı altında iki farklı tür olduğunu göstermektedir.

Tablo 1'de yer alan Atay (1985) ve Tokaç vd. (2010) hariç tüm yazarlar *L. amia* için akya adını kullanmışlardır. *S. dumerili* nin Türkçe adı Caferoğlu (1960) ile Palombi ve Santarelli (1969)'nin kullandığı akya hariç tüm yazarlar tarafından sarı kuyruk olarak verilmiştir. *Trachinotus ovatus* (Linnaeus, 1758) (Yaladerma) konu dışı olmasına karşın, bazı yazarlarca

yanlışlıkla çıplak, liça ve çatal kuyruk olarak tanımlanıp isimlendirildiği ve *L. amia* ile *S. dumerili* için oluşan isim boşluğundan akya ve sarı kuyruk isimlerine yer açtığı görülmektedir (Geldiay, 1969; Geldiay, 1976; Mater ve diğ, 1989; Mater ve Meriç, 1996; Mater vd., 2003; Can ve Bilecenoğlu, 2005; Turan, 2007; Tıraşın ve Ünlüoğlu, 2012). *S. dumerili*'nin sarı kuyruk şeklinde bir başka dilden alınıp devşirme kullanımı balık isimlendirmelerinde görülen bir durumdur ancak balığın Türkçe veya yerel adının olmaması durumunda uygulanması gereken bir yöntemdir.

Julian (2017)'de gerçekleştirdiği yüksek lisans tezinde; Gökoğlu ve Oray (1992)'deki çalışmalarında kılıç balığı paragatlarına takılan *L. amia*'nın kılıç paragatında yakalanamayacak kadar sığ ve 50 m geçmeyen kıyısal acısu ortamlarını tercih ettiğini, burada yakalanan türün *S. dumerili* olması gerektiğini, balıkçıdan akya diye alınan verinin yanlışlıkla *L. amia* olarak kayda geçtiğinden söz etmektedir. Bu ve benzeri durumların mevcut isim kargaşasından dolayı yaşanması kaçınılmazdır.

Balık yetiştiriciliğini konu alan çalışmalarda dünyanın farklı bölgelerinde bulunan *Seriola* spp. için İngilizce "Yellow tail" sarı kuyruk isminin kullanıldığı görülmektedir. Oysa iki tür *S. quinqueradiata* ve *S. lalandi* genel görünüşü ile sarı kuyruk olarak adlandırılmaktadır. İngilizce "Greater amberjack" olan *S. dumerili*, dünyanın farklı bölgelerinde kültür balıkçılığı yapılan *Seriola* spp. ile birlikte ticari kolaylık ve pazarlama stratejisi için ortak bir isim olan sarı kuyruk olarak pazarlanmaktadır (Alpbaz, 2005; Atay, 1985; Sicuro ve Luzzana, 2016). Balıkçılarımız tarafından kullanılmayan sarı kuyruk isminin yaygınlaşmasının sebeplerinden birini bu durum oluşturmaktadır.

Su ürünleri istatistiklerinin yer aldığı 1967-2021 arasında akya'nın İngilizce Leerfish adıyla belirtilmesi *L. amia* olarak kayıt edildiğini göstermektedir. Su ürünleri istatistiklerinde 2004 yılına kadar avcı için yöresel ürün ve İngilizce karşılığı bilinmiyor notu düşülmüştür. 2004 ile birlikte avcının İngilizce karşılığı "Greater amberjack" olduğu yani *S. dumerili* olarak kaydedildiği görülmektedir (TÜİK, 2004-2021).

Ancak balıkçılarımız çok yaygın bir şekilde 10 ilimiz kıyılarını kapsayan Ege ve Akdeniz bölgesinde *S. dumerili* için akya ismini kullanmaktadır. Balıkçılardan alınan akya av bilgilerinin istatistik verilerine *L. amia* olarak girildiğini göstermektedir. Ayrıca 1965 yılı Nisan ayı İzmir balık hali av verilerinde akya ve çıplak olarak ayrı ayrı verilmiş olması akya'nın balıkçılar tarafından *S. dumerili* için kullanıldığını, çıplak isminin ise *L. amia* için kullanıldığının bir delilini oluşturmaktadır (Akagündüz, 1965). Karapınar (1965) akya ve çıplak adı altında iki türün İzmir halinde ayrı ayrı kaydı tutulmakta olduğunu ve bazı balıkçıların zaman zaman bu iki türü karıştırdığının sözünü etmektedir. Ocak 1962 su ürünleri mahsulleri istihsalinde İzmir, Fethiye, Finike, Alanya, Taşucu bölgelerinde akya'ya ait av verileri bulunması *S. dumerili*'nin akya olarak eskiden bu yana kullanıldığını göstermektedir (Canyiğit, 1962). Arazi çalışmaları ve eski balık hali verileri göz önüne alındığında *L. amia*'nın *S. dumerili* kadar av vermediği görülmektedir. Su ürünleri istatistiklerinde Türkçe ve yöresel adı akya ve avcı olarak kaydedilen iki tür aslında *S. dumerili olarak* tek bir türü kapsadığı gibi akya nın iki türün verisinden oluşma olasılığı da yüksektir (Şekil 2 ve 3).

Denizlerde ve içsularda ticari ve amatör amaçlı su ürünleri avcılığını düzenleyen sirküler ve tebliğlerde 1997- 2004 arası dönemini kapsayan sirkülerde *L. amia* için akya adı geçmektedir. Denizlerde ve içsularda ticari amaçlı su ürünleri avcılığını düzenleyen 36/1, 37/1 no'lu sirküler döneminde *L. amia* için kullanılan Türkçe isim akya olarak kalırken, *S. dumerili* için sarı kuyruk adı kullanılmaya başlamıştır. Oysa daha önce avcı adı ile sadece bilgi notu olarak yer alır iken 2004-2006 dönemi ile sarı kuyruk adı altında boy ve değişik av kısıtlamaları belirtilmiştir (TKB, 1997, 2004, 2006). Tarım bakanlığı koruma kontrol genel müdürlüğü ve balıkçılık genel müdürlüğü *S. dumerili* için Türkçe isim değişikliğine giderek avcı yerine sarı kuyruk adını kullanmıştır. TÜİK ise su ürünleri istatistiklerinde benzer bir tutum içine girmeyerek sarı kuyruk ismini kullanmamıştır. Balık türlerini içeren su ürünleri istatistik bilgilerinin doğru girilmesi geleceğe yönelik tedbirlerin alınabilmesi açısından büyük önem taşımaktadır.

SONUÇ

Balık türlerinin isimlendirilmesi, konunun uzmanları ile saha çalışmaları yapılıp yürütülmesi ve çalışmaların sağlıklı olması açısından önem arz etmektedir. Balıkların yerel isimleri genelde, şekil, renk, büyüklük, bir başka obje veya canlıya benzetilerek genellikle balığı tutan balıkçılar tarafından verilmektedir. Bu açıdan balıkçıların kullandıkları isimlerin göz ardı edilmemesi gereklidir. Balıkların doğru teşhisi ve doğru isimlendirilmesi için akademisyenlerin balıkçılar ile aynı isimleri kullanmaları gereklidir. Devletin ilgili kurumlarında çalışan görevliler, balığın karaya çıkış noktaları ve balık hallerinde aldıkları verilerin sağlıklı olması için balıkları iyi tanımalı ve yerel isimlerini doğru kullanabilmelidirler. Çalışmanın tartışma bölümü saha çalışmalarında balıkçıların konuya yaklaşımı, amatör balıkçıların bakışı ve mevcut literatürün konuya katkısının ne yönde olduğu, şeklinde değerlendirilmiştir. Buna göre *S. dumerili* için Türkçe isminin "Akya" olarak kullanılması doğru olacaktır. Akya'nın yanında kuzu, avcı ve imtiyaz bölgesel olarak kullanılan diğer yerel isimlerdir. *L. amia* için Türkçe isminin "Çıplak" olarak kullanılması gerektiği sonucu ortaya çıkmıştır. Ayrıca çıplak'ın yanında yerel isimler olarak liça, çatal kuyruk ve akya fulya kullanıldığı görülmektedir. Bu çalışma, balıkçılık verilerinin doğru elde edilmesi, türlerin korunması ve stokların yönetimine temel teşkil edecek uygulamalara katkı sağlayacaktır. Konunun uzmanlarınca Türkçe isimlerinde karışıklık olan diğer balık türlerine yönelik çalışmaların yapılmasının gerekli olduğu sonucu ortaya çıkmaktadır.

TEŞEKKÜR VE MADDİ DESTEK

Bu araştırma, kamu, ticari veya kâr amacı gütmeyen sektörlerdeki herhangi bir finansman kuruluşundan belirli bir hibe, fon veya başka bir destek almamıştır.

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Mevcut çalışma sırasında oluşturulan ve/veya analiz edilen veri setleri, editör veya hakemlerin talebi üzerine ilgili sorumlu yazar tarafından sağlanacaktır.

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SHORT COMMUNICATION KISA MAKALE

The translocation of a native fish for recreational purposes: First record of *Abramis brama* (Linnaeus, 1758) in Büyükçekmece Reservoir (İstanbul, Türkiye)

Yerli bir balığın rekreasyonel amaçlarla yer değiştirmesi: *Abramis brama* (Linnaeus, 1758) 'nın Büyükçekmece Rezervuarı (İstanbul, Türkiye)'ndan ilk kaydı

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Abstract: The present study documented the first record of the common bream, *Abramis brama* (Linnaeus, 1758), in the Büyükçekmece Reservoir (İstanbul, Türkiye). The fish were found to have been translocated into the reservoir by anglers from the native population of Lake Durusu (İstanbul). With this discovery, the number of fish species living in the reservoir has increased to 25.

Keywords: Bream, fish fauna, Leuciscidae, translocated species

Öz: Bu çalışma, Büyükçekmece Rezervuarı (İstanbul, Türkiye)'ndan çapak balığı *Abramis brama* (Linnaeus, 1758)'nın ilk kaydını sunmaktadır. Balıkların, Durusu Gölü (İstanbul)'nün yerli popülasyonundan balıkçılar tarafından rezervuara taşındığı tespit edilmiştir. Bu bulgu ile birlikte rezervuarda yaşayan balık türü sayısı 25'e yükselmiştir.

Anahtar kelimeler: Çapak balığı, balık faunası, Leuciscidae, taşınmış tür

INTRODUCTION

The intentionally translocation and introduction of a fish species into new habitats is usually done for the purpose of stocking, which helps to support fisheries, or for recreational and sport fishing. 'Translocation' refers to the transfer of a species from one part of a country where it is native to another part of the same country where it is not native, whereas 'introduction' is the reverse: it is the deliberate or accidental transfer and/or release, by direct or indirect human agency, of a species into geographical areas where the taxon is not native (Copp et al., 2005). Recreational anglers, in particular, are responsible for the direct or indirect transfer of many native species between neighbouring water systems or outside their native range (Pérez-Bote and Roso, 2014). However, even with good intentions, most translocated species can become naturalised in their new habitats and such activities can pose a major threat to native species or ecosystems (Pofuk et al., 2017).

Lake Büyükçekmece, which has undergone many changes in terms of its ecosystem characteristics from the past to the present, was turned into a reservoir in 1985 to meet the water needs of the growing population of the metropolis İstanbul. From being a lagoon used by 30 species, it has become a freshwater lake, especially where freshwater forms predominate with a relatively lower number of species (Meriç, 1986; Meriç, 1992; Özuluğ, 1999; Saç and Özuluğ, 2017). Fishing activities have led to the translocation and introduction of some native and non-native/invasive fish species into the lake. It was reported that *Silurus glanis* was first translocated here from Lake Durusu (İstanbul) in 1989, and in the following years, the non-native *Carassius gibelio* was introduced by fishermen from Kayalı Reservoir (Meriç, 1992; Özuluğ, 1999) and it has become one of the dominant fish species with its highly invasive characteristics (Saç and Okgerman, 2015). According to recent literature, the reservoir is currently home to 24 fish species, some of which are of marine origin (Özuluğ, 1999; Saç et al., 2015; Saç et al., 2016).

Here, we report for the first time *Abramis brama* as a new translocated species from the Büyükçekmece Reservoir.

MATERIALS AND METHODS

Fish samples were collected on two different dates, 23 February 2024 and 2 March 2024, from the gill nets (mesh size 60×60 mm) cast by a fisherman as part of another project (Scientific Research Projects Coordination Unit of İstanbul University with project number FYL-2023-40388; İstanbul University Local Ethics Committee for Animal Experiment

Decision with number: 2023/26) in the Büyükçekmece Reservoir (Figure 1). After immediate capture, fish specimens were transferred to the İstanbul University Biology Department Environmental Biology and Ecology Laboratory under cold conditions (+4°C). Fish samples were measured to the nearest 0.1 cm for total length (TL) and weighed to 0.01 g for body weight. Kottelat and Freyhof (2007) were used for species identification.

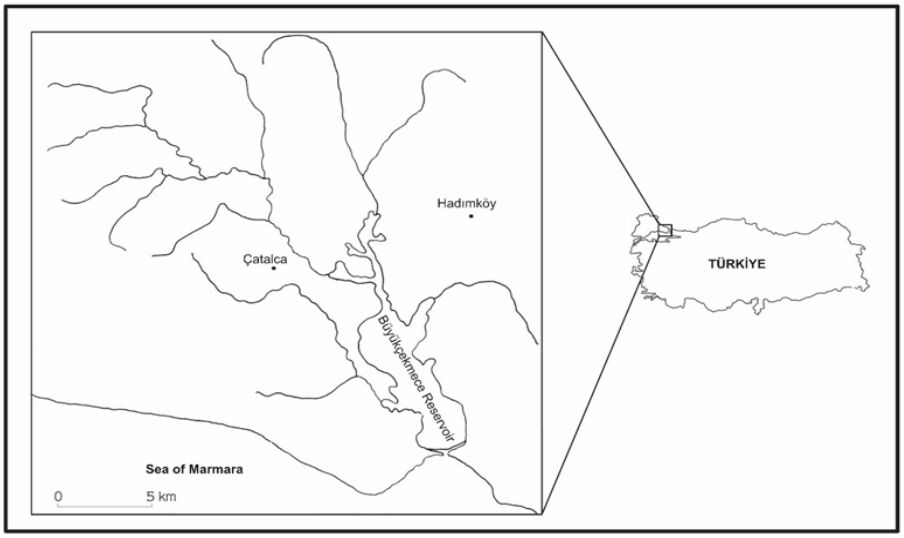

Figure 1. Map of Büyükçekmece Reservoir.

RESULTS AND DISCUSSION

In total, two individuals were caught in different dated samplings. The total length and weight of the fish caught in February were 44.5 cm and 1222.10 g, while the fish caught in March were 42.9 cm and 900.95 g (Figure 2). Interviews with anglers revealed that the fish had been introduced into the reservoir from Lake Durusu about ten years ago and had been caught frequently, especially in recent years. Considering both the date of translocation of the fish into the reservoir and the fishing gear used in the samplings, the size distribution of the individuals caught is within the expected range.

Figure 2. *Abramis brama*, 44.5 cm TL, Büyükçekmece Reservoir (İstanbul, Türkiye)

Abramis brama typically shows ontogenetic shifts in diet and habitat, from feeding on zooplankton in pelagic habitats to feeding on benthic invertebrates buried in the sediment (Persson and Brönmark, 2002). Therefore, this species can be very popular with fishermen as it can be ready to eat within a few years due to its rapid growth pattern which is observed especially in early ages (Tierney et al., 1999; Stankus, 2006; Adrović et al., 2009). It has been deliberately introduced into many countries outside its natural range because of its popularity in sport fishing and as a food source for commercial purposes (Tierney et al., 1999; Pino-del-Carpio et al., 2010). Apart from its native distribution range, this fish, which has been introduced to the Lake Baikal and upper Ob and Yenisei drainages (Kottelat and Freyhof, 2007), is thought to have been translocated to some reservoirs

(such as Hasan Uğurlu and Suat Uğurlu reservoirs and Güven Pond) in Türkiye, as well (Uğurlu, 2006).

There are no records of *A. brama* exhibiting invasive behaviour in the countries where it has been introduced but its impact mechanisms recognised as habitat and ecosystem alteration in Mexico (Pino-del-Carpio et al., 2010). Besides, it is inevitable that it can compete for food and habitat with native fishes (i.e. *Rutilus rutilus*, *Scardinius erythrophthalmus*) at similar trophic levels. Interviews with local anglers indicated that *A. brama* is represented in relatively low numbers in the reservoir in terms of catch values compared to other fishes. However, it is particularly necessary to monitor the population size of the species and its relationship with native fishes in the Büyükçekmece Reservoir, which is now a sensitive ecosystem due to periodic water withdrawals or regional droughts and the current invasive species (*C. gibelio* and *Gambusia holbrooki*).

In conclusion, the present study gives the first record of *A. brama* translocated to Büyükçekmece Reservoir. Commercial fishing is banned indefinitely in this reservoir, which is used as a source of drinking and utility water. However, angling continues throughout the year, which can make the reservoir an open area for fish introductions. It is therefore very important to increase inspections by the competent authority and to raise awareness among the local people in order to prevent the translocation or introduction of uninvited fish and to protect native biodiversity.

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AUTHORSHIP CONTRIBUTIONS

All authors contributed equally to the conception, laboratory work, and design of the study.

CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

ETHICS APPROVAL

According to the national guidelines for animal care, this study was conducted with the permission of İstanbul University Local Ethics Committee for Animal Experiments (Date: 04.09.2023, No: 2023/26).

DATA AVAILABILITY

All relevant data is in the article.

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REVİEW DERLEME

Effective herbal therapeutics against the protozoan parasites in aquaculture

Su ürünleri yetiştiriciliğinde protozoan parazitlerine karşı etkili bitkisel ilaçlar

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Abstract: In industrial aquaculture, producing at high stock densities is inevitable to maximize efficiency and harvest per unit volume. Antibiotics, disinfectants, and other chemicals have become necessary to prevent and control disease outbreaks in intensive fish farming practices. However, the negative impacts of the use of synthetic chemical drugs on environmental health have sparked discussions, making research into alternative treatments inevitable. Medicinal plants offer promising solutions for disease control due to their natural, biodegradable, and antimicrobial properties. The therapeutic properties of plants have been known and safely used in traditional medicine for a long time. The idea that medicinal plants can be utilized in aquaculture as a safer, sustainable, and environmentally friendly practice has begun to be embraced. Although numerous treatment protocols have been developed against metazoan parasites in aquaculture, managing protozoan parasites still poses a significant challenge. A detailed literature review has identified that more than 30 plant species have the potential to control many protozoan pathogens in fish, including *Ichthyophthirius multifiliis* and *Cryptocaryon irritans*. Studies highlight the effectiveness of plant-derived compounds in combating parasites and promoting growth, supporting immunity, serving as antibacterial agents, and even as anaesthetics. Since research on medicinal plants predominantly targets commercially valuable fish farming, there is a recognized need for expanded studies on their application in shellfish farming. Collaboration among researchers, institutions, and farmers is crucial in increasing awareness of local medicinal plants and promoting their use. The use of plants with medicinal properties in aquaculture represents a promising path for disease control and sustainable production. Adopting these natural alternatives could align with responsible agricultural practices and meet the urgent need to mitigate the environmental impacts of traditional treatments in the aquaculture industry.

Keywords: Medicinal plants, herbal therapeutics, protozoan, antiparasitic, aquaculture

INTRODUCTION

In industrial aquaculture, high stock densities and specially formulated feeds are essential to achieve better yield advantages per unit volume. It is an international reality that fish farmers must use large quantities of antibiotics, disinfectants, and other chemical preparations to control mortality rates and prevent significant financial losses from disease outbreaks. Moreover, the use of artificial drugs and chemical therapies, which can damage the natural ecological structures in both water and soil, has been the subject of global and local debates for the past twenty years due to their potential to create adverse effects on the environment and human health. Many alternative methods are being developed to minimize the negative impacts of current treatment practices in aquaculture. While studies on the development and widespread adoption of vaccines and immune enhancers, particularly Specific Pathogen Free (SPF) varieties, continue, developing therapeutic natural alternatives to combat common disease agents has become necessary under increasing environmental sensitivity.

The therapeutic effects of medicinal plants have been known for many years in traditional medicine and pharmacology. It is also reported that this knowledge has been experimentally used in small enterprises against various infections in terrestrial animals and sometimes fish. Medicinal plants are considered safe and highly potent due to their natural, biodegradable, and antimicrobial properties (Valladão et al., 2015). At the same time, more information is available on the identification and treatment of viral, bacterial, and fungal diseases, as well as metazoan parasites, than on protozoan parasites. Pathological tissue changes such as hyperplasia, hypertrophy, or necrosis in protozoan infections can be confused with pathologies caused by many other pathogens. Protozoan parasites can cause acute and chronic detrimental effects in the aquaculture of fish and shellfish (Buchmann, 2015).

Responsible agricultural practices prioritize an ethical approach that avoids using substances harmful to humans and the environment during cultivation stages. In the fight against climate crisis and strategies to reduce water and environmental pollution, limiting the use of harmful

substances and synthetic chemicals forms the basis of the transition to good agricultural practices. The approach that medicinal plants can also be utilized to combat diseases in good agricultural practices has started to be adopted.

To date, the potential of phytochemicals (plant derived chemicals) derived from over 30 different plant species to prevent and control unicellular parasites such as Ichthyophthirius *multifiliis*, *Cryptocaryon irritans*, *Piscinoodinium pillulare*, *Ichthyobodo necator*, *Trichodina* sp., *Scuticociliates* sp., and *Hexamita* sp. in freshwater and marine organisms has been researched (Bulfon et al., 2015).

The primary purpose of this review is to raise awareness among decision-makers about medicinal plants as alternative treatment methods in the industrial aquaculture sector and to encourage future research within the scope of responsible aquaculture and agricultural ethics. In this context, medicinal plants proven effective in aquaculture and experimental infections, along with their application protocols, have been listed, and a reference has been prepared for those interested in use.

Application of herbal supplements in aquaculture as anti-protozoan therapeutics agents

Numerous studies have been conducted against unique unicellular pathogenic parasitic agents commonly causing diseases in aquaculture environments. The effectiveness of various plant extracts has been extensively listed against pathogenic protozoan parasites (*in vivo* and *in vitro*), including *I. multifiliis*, *C. irritans*, *P. pillulare*, *I. necator*, *Trichodina* sp., *Gregarines sporozoites*, *Scuticociliates*, and *Hexamita* sp. agents. Previous studies offering environmentally sensitive alternative treatment methods in aquaculture have primarily focused on mitigating serious protozoan infections (Table 1).

Ichthyophthiriasis is among the most significant protozoan diseases, especially in freshwater fish. A study on the antiparasitic efficacy of Magnolol, extracted from plants of the *Magnolia* genus (*M. officinalis* and *M. grandiflora*) used in traditional Chinese and Japanese medicine, reported 100% effectiveness against *I. multifiliis* theronts under in vitro experimental conditions. It was reported to inhibit protomont and tomont cyst development at concentrations of 0.6 mg/L or higher and for 6 hours at 0.8 mg/L and 1.0 mg/L, respectively. An experimental *I. multifiliis* infection in goldfish (*Carassius auratus*) showed that a 5-hour bath treatment with 1.5 mg/L Magnolol significantly reduced the number of theronts released from tomonts in infected fish (Song et al., 2018). The phytochemical 10-gingerol isolated from extracts of *Zingiber officinale* has been reported to protect grass carp (*Ctenopharyngodon idella*) against *I. multifiliis* infection when administered as a bath treatment at a dose of 4 mg/L for 10 days (Fu et al., 2019). The compound 10-gingerol extracted from *Z. officinale* demonstrated 100% antiprotozoal activity against encysted tomonts, nonencysted tomonts, and theronts at concentrations of 16, 8, and 2 mg/L, respectively, in laboratory conditions (without the use of live experimental animals, in petri dishes). The application of tea tree oil (*Melaleuca alternifolia*) at a dose of 50 µL/L for 1 hour per day over 4 days has been recorded to be effective in the treatment of Ichthyophthiriasis in South American catfish (*Rhamdia quelen*) and significantly reduced hepatic oxidative stress (Baldissera et al., 2017).

Based on *in vitro* antiparasitic analyses, the phytochemicals Chelerythrine and Chloroxylonine obtained from the *Toddalia asiatica* plant showed 100% effectiveness at concentrations of 1.2 and 3.5 mg/L, respectively, after 4 hours. Additionally, when 1.8 mg/L Chelerythrine and 8.0 mg/L Chloroxylonine were applied as a bath for 72 hours to infected goldfish (*C. auratus*), they exhibited low parasite prevalence compared to the control group (Shan et al., 2014).

Ekanem et al. (2004) reported that an extract obtained from *Mucuna pruriens* leaves using crude methanol (200 mg/L bath/72 hours) and an extract obtained from the seeds of *Carica papaya* using petroleum ether (250 mg/L bath/96 h) helped significantly reduce parasite load and fish mortality in goldfish with Ichthyophthiriasis, and the extracts could be effectively used. The same researchers reported that *M. pruriens* and *C. papaya* extracts, when used at concentrations of 150 mg/L and 200 mg/L for 6 hours, killed the *I. multifiliis* pathogen 100%.

In the case of grass carp (*C. idella*) infected with *I. multifiliis*, the antiparasitic effect of the chemical Sanguinarine derived from the leaves of *Macleaya cordata* (0.9 mg/L 48-hour bath) proved to be 96.8% effective. Moreover, experimental parasite inhibition tests conducted without fish have reported that chloroform and ethanol extracts from *M. cordata* at a concentration of 70.0 mg/L for 4 hours demonstrated 100% effectiveness against Ichthyophthiriasis (Yao et al., 2010).

In *I. multifiliis* infected barbel chub (*Squaliobarbus curriculus*), the active components Dihydrosanguinarine and Dihydrochelerythrine isolated from *Macleaya microcarpa* leaves were effective in bath doses of 5.18 and 9.43 mg/L for 48 hours, respectively (Yao et al., 2011a).

In goldfish (*Carassius auratus*) infected with *I. multifiliis*, the use of a water-based extract derived from the *Capsicum frutescens* plant at dilutions of 1:32 and 1:64 (for a 4-hour bath) reduced parasite infection prevalence by 13.3% and 40% respectively (Ling et al., 2012). In another study, goldfish treated with methanol extracts obtained from *Magnolia officinalis* and *Sophora alopecuroides* showed a reduction in theronts by 24.7% and 44.7%, respectively, after a 1-hour bath treatment at concentrations of 40 and 320 mg/L (Yi et al., 2012).

In channel catfish (*Ictalurus punctatus*) infected with *I. multifiliis*, treatment with Pentagalloylglucose derived from the *Galla chinensis* plant (20 mg/L/10 days/bath) has been reported to increase fish survival rates up to 93.3%. Antiparasitic assesments in cell culture have shown that Pentagalloylglucose eliminated all theronts (at concentrations of 2.5-20 mg/L over 5.6-233.9 minutes) and reduced tomont

Table 1. A summary of effective herbal therapeutic agents in finfish and shellfish protozoan parasites infection applied in finfish and shellfish aquaculture

In vivo* and *In vitro	**Parasite**	**Agent, dosage, time, and administration**	**Effect***	**Reference**
Goldfish (*C. auratus*)	*I. multifiliis*	Magnolol 1.5 mg/L/5 h, bath	Theronts number ↓ Theronts mortality ↑↑↑	Song et al. (2018)
In vitro		0.6 mg/L/4 h 0.8 mg/L/6 h 1.0 mg/L/6 h	Protomont ↓ Tomont ↓	
Grass carp (*C. idella*)	*I. multifiliis*	10-gingerol 4 mg/L /10 d., bath	+, Fish survival rate↑ Encysted tomonts mortality↑↑↑	Fu et al. (2019)
In vitro		16 mg/L 8 mg/L 2 mg/L	Nonencysted tomonts mortality ↑↑↑ Theronts mortality ↑↑↑	
Silver catfish (*R. quelen*)	*I. multifiliis*	*Melaleuca alternifolia* essential oil. Tea tree oil 50 µL/L/1h/d/4 d, bath	Hepatic oxidative stress↓	Baldissea et al. (2017)
In vitro		*Mucuna pruriens* 150 mg/L/6 h *Carica papaya* 200 mg/L/ 6 h	↑↑	
Goldfish (*C. auratus*)	*I. multifiliis*	Antiparasitics from *Toddalia asiatica* Chelerythrine1.8 mg/L, bath Chloroxylonine 8.0 mg/L/72 h	Parasite prevalence ↓ Parasite Prevalence ↓	Shan et al. (2014)
In vitro		Chelerythrine 1.2 mg/L/4 h Chloroxylonine 3.5 mg/L/4 h	↑↑ ↑↑	
Goldfish (*C. auratus*)	*I. multifiliis*	Crude methanolic extract *Mucuna pruriens,* 200 mg/L/72 h, bath Petroleum-ether extract of *Carica papaya*, 250 mg/L/96 h, bath	↑↑, Fish mortality↓ ↑↑, Fish mortality ↓↓	Ekanem et al. (2004)
In vitro		*Mucuna pruriens* 150 mg/L/6 h *Carica papaya* 200 mg/L/ 6 h	↑↑	
Grass carp (*C. idella*)	*I. multifiliis*	Sanguinarine (*Macleaya cordata*) 0.9 mg/L/48 h, bath	↑↑	Yao et al. (2010)
In vitro		Chloroform ethanol extract *M. cordata* of 70.0 mg/L/4 h	↑↑	
Barbel chub (*S. curriculus*)	*I. multifiliis*	Dihydrosanguinarine (*Macleaya macrocarpa*) 5.18 mg/L Dihydrochelerythrine 9.43 mg/L/48 h	+	Yao et al. (2011a)
In vitro		Two compounds (crystals) were separated from Fraction B compound 1 7.0 mg/L/4 h Compound 2 10.0 mg/L/4 h	↑↑ ↑↑	
Goldfish (*C. auratus*)	*I. multifiliis*	Aqueous extract *Capsicum frutescens* 1:32- 1:64/4 h, bath	Parasite prevalence ↓	Ling et al. (2012)
Goldfish (*C. auratus*)	*I. multifiliis*	Methanol extracts *Magnolia officinalis* 40 mg/L and *Sophora alopecuroides* 320 mg/L/1 h, bath	Tomont survival ↓	Yi et al. (2012)
Channel catfish (*I. punctatus*)	*I. multifiliis*	Pentagalloylglucose from *Galla chinensis* 20 mg/L/10 d, bath	Fish survival ↑	Zhang et al. (2013)
In vitro		2.5-20 mg/L/5.6-233.9 min 40 mg/L	Theronts mortality ↑↑↑ Tomonts reproduction ↓↓	
In vitro	*I. multifiliis*	Sage *(S. officinalis)* 0.50 mL/L, *lavender (L. officinalis)* at 0.25-0.50 mL/L, *and* oregano *(O. onites)* at 0.1, 0.25, 0.50mL/L/60 min, Onion (*A. cepa*), menthe (*M. spicata*), and garlic (*A. sativum*) essential oils at 0.1, 0.25, 0.50mL/L/60 min	Anti-trophonts ↑↑	Özil (2023)
Grass carp (*C.idella*)	*I. multifiliis*	Commercial curcumin from *Curcuma longa* plant at 4 mg/L/10 d., bath	Anti-trophonts ↑↑ Fish	Liu et al. (2017)
In vitro		Curcumin 1 mg/L/38.7 min, 8 mg/L/47.3 min and at 4 mg/L/16 h	Theronts mortality ↑↑↑,	
Grass carp (*C. Idella*)	*I. multifiliis*	*Cynanchum atratum* and *Sophora flavescens* combination as 6 mg/L/10 d, bath	Infection intensity ↓↓, Fish	Fu et al. (2021)
In vitro		Ethanol extract of *Psoralea corylifolia* 4 mg/L/37 min, *Cynanchum atratum* 8 mg/L/197 min	Theronts mortality ↑↑↑,	

*↑↑↑: 100%, ↑↑: antiprotozoal efficacy >75%, ↓↓: completely eliminated +: express as an effective without specific rate, ↑: increased, ↓: decreased. µL: micro liter, ML: milliliter, L: Liter, mg: milligram, g: gram, kg: kilogram, min: minute, h: hour, d: day, w: week.

Table 1. (Continued)

In vivo and In vitro	Parasite	Agent, dosage, time, and administration	Effect*	Reference
Goldfish (*C. auratus*)	*I. multifiliis*	Dietary *Artemisia annua* 20 g/kg/45 d	Trophonts ↓, fish survival ↑	Wu et al. (2017)
Goldfish (*C. auratus*)	*I. multifiliis*	Dietary Magnolol (*Magnolia officinalis*) 90 mg/kg/d/3 d	Fish survival ↑	Zhang et al. (2022)
Tambaqui (*C. macropomum*)	*I. multifiliis*	Essential oil of *Lippia alba* at 150 mg/L/30 min, bath	Antiprotozoal efficacy ↑	Soares et al. (2016)
Pacu (*P. mesopotamicus*)	*I. multifiliis*	*Melaleuca alternifolia* essential oil 50 µL/L/2 h/d/5 d, bath	↑↑↑, Fish survival rate ↑	Valladão et al. (2016)
In vitro		*Melaleuca alternifolia, Lavandula angustifolia,* and *Mentha piperita* essential oils 455 µL/L/1 h or 227µL/L/4 h	Trophont mortality ↑↑↑	
Molly (*P. latipinna*)	*I. multifiliis*	Garlic (*A. sativum*) 0.1 g/L and *Matricaria chamomilla* extract 0.4 g/L />5 d., bath	Antiprotozoal efficacy ↑↑↑	Gholipour-Kanani et al. (2012)
Silver catfish (*R. quelen*)	*I. multifiliis*	*Hyptis mutabilis* leaf essential oil 20 mg/L/96 h, bath	Fish survival ↑↑↑	Da Cunha et al. (2017)
Tambaqui (*C. macropomum*)	*I. multifiliis*	*Varronia curassavica* essential oil VCUR-202 accession 0.5 and 2.0 mg/L/1 h bath	Trophonts on infected fish ↓	de Castro Nizio et al. (2018)
In vitro		Essential oil of the VCUR-202 accession 10 mg/L/1 h, 50 mg/L/1 h	Trophonts mortality ↑↑↑	
Pompano (*Trachinotus ovatus*)	*C. irritans*	Dietary Honokiol 400 mg/kg/7 d	Trophonts ↓, Fish survival ↑	Zhong et al. (2019)
Tambaqui (*C. macropomum*)	*Piscinoodinium pillulare*	*Mentha piperita* (peppermint) essential oil 20 mg/L/3 d/24-h intervals,10 min bath	Parasite load reduction ↑	Ferreira et al. (2019)
Salmon (*Oncorhynchus. keta*) and (*O. masou*)	*Ichthyobodo necator*	Green tea extract (*Camellia sinensis*) Epigallocatechin gallate 0.9%/5 min, bath	↑↑	Suzuki et al. (2006)
Tilapia (*O. niloticus*)	*Trichodina* sp.	Extracts of *A. sativum* and *Terminalia catappa* 800 mg/L/2 d, bath	↓↓	Chitmanat et al., (2005)
Tilapia (*O. niloticus*)	*Trichodina* sp.	*Camellia sinensis* extract 0.9%/5 min, bath	↓	Noor El-Deen, (2010)
Parabramis pekinensis	*Trichodina* sp.	*Chelidonium majus*, chelidonine 1.0 mg/L, chelerythrine 0.8 mg/L, and sanguinarine 0.7 mg/L/48 h, bath	↑↑	Yao et al., (2011b)
Tilapia *(O. niloticus)*	*Trichodina* sp.	Garlic powder 300 mg/L, and garlic oil 3 g/L/1 h, bath	Parasitized fish ↓	Abd El-Galil and Aboelhadid, (2012)
Goldfish (*C. auratus*)	*Trichodina* and *Tripartiella*	Dietary *Swietenia mahagoni* extract 8 g/kg/5 d and *Cinnamomum tamala* 4-8 g/kg/15 d	+	Saha et al. (2020)
Tilapia (*O. niloticus*)	*Trichodina* sp.	Dietary garlic and Sheh el-baathran 1 g/kg/15 d	Parasite number and Fish	Aboud (2010)
White shrimp (*L. vannamei*)	*Gregarines* sporozoites	Dietary garlic paste (allicin) 40-50 g/kg	+, Number of sporozoites in intestine↓.	Madhuri et al. (2021)
Olive flounder (*Paralichthys olivaceus*)	*Uronema marinum*	*Punica granatum*, *Chrysanthemum cinerariaefolium*, *Zanthoxylum schinifolium* 5 mg/kg/6 d, extract injection	Mortality of fish ↓, Phagocytic activity ↑	Harikrishnan et al. (2010)
Olive flounder (*P. olivaceus*)	*Philasterides dicentrarchi*	Dietary *Hericium erinaceum* 0.1-1.0%/4 w	Immune response ↑, Mortality of fish ↓	Harikrishnan et al. (2011a)
Grouper (*Epinephelus bruneus*)	*Philasterides dicentrarchi*	Dietary *Kalopanax pictus* extract 1.0-2.0% for 30 d	Phagocytic/complement activity ↑, Mortality of fish ↓	Harikrishnan et al. (2011b)
Olive flounder (*P. olivaceus*)	*Miarniensis avidus*	Dietary *Suaeda maritima* 1.0%/4 w	Serum lysozyme, scuticocidal, respiratory burst activity ↑, Mortality of fish ↓	Harikrishnan et al. (2012)
Angelfish (*Pterophyllum. scalare*)	*S. vortens Hexamita*)	Dietary 0.5% Metronidazol (MTZ) and 0.5% Ajoene oil/5 d	Fecal trophozoite count. ↓	Williams et al. (2016)
In vitro		Synergetic effects tested MTZ and Ajoene oil	MTZ, min inhibition concentration (MIC) ↓	
In vitro	*Hexamita*	*Lavandula angustifolia* and hybrid lavandula essential oils 0.5-1%/30 min	Parasite mortality ↑	Moon et al. (2006)

*↑↑↑: 100%, ↑↑: antiprotozoal efficacy >75%, ↓↓: completely eliminated +: express as an effective without specific rate, ↑: increased, ↓: decreased. µL: micro liter, ML: milliliter, L: Liter, mg: milligram, g: gram, kg: kilogram, min: minute, h: hour, d: day, w: week.

reproduction at a concentration of 40 mg/L (Zhang et al., 2013). Özil (2023) reported that laboratory-based (*in vitro*) activity tests demonstrated 100% anti-trophont (*I. multifiliis*) efficacy after 60 minutes of application for essential oils derived from common sage, *Salvia officinalis* (0.50 mL/L), lavender, *Lavandula officinalis* (0.25 and 0.50 mL/L), and oregano, *Origanum onites* (0.1, 0.25, and 0.50 mL/L). Additionally, essential oils from onion (*Allium cepa*), mint (*Mentha spicata*), and garlic (*Allium sativum*) displayed anti-trophont activity ranging from 75-94%, 84-94%, and 72-92% at dosages of 0.1, 0.25, and 0.50 mL/L respectively.

In grass carp (*C. idella*) infected with the protozoan parasite (*I. multifiliis*), it was reported that curcumin, derived from the plant *Curcuma longa*, when applied at a dosage of 4 mg/L per bath for 10 days, inhibited all parasitic trophonts and showed a 100% fish survival rate. In vitro trials also revealed that curcumin at doses of 1 mg/L for 38.7 minutes, 8 mg/L for 47.3 minutes, and 4 mg/L for 16 hours completely killed theronts and all encysted tomonts (Liu et al., 2017).

A study by Fu et al. (2021) examined the synergistic and additive effects of medicinal plant combinations in combating *I. multifiliis* infections. They found high efficacy in grass carp infected with twenty-one combinations, particularly with plants *Cynanchum atratum* and *Sophora flavescens* at a dose of 6 mg/L for 10 days per bath treatment, recording zero infection intensity and 100% fish survival rate. In vitro results also found that the ethanol extract of the *Psoralea corylifolia* plant at a dose of 4 mg/L for 36.7 minutes and the extract of the *Cynanchum atratum* plant at a dose of 8 mg/L for 196.7 minutes completely killed theronts and non-encysted tomonts.

A study examining the pharmacokinetics of magnolol, a phytochemical from the *Magnolia officinalis* plant, in goldfish (*C. auratus*) determined that the oral route was the best method of administration. An effective dose of magnolol was established at 90 mg/kg of fish per day for 3 days, which showed promising results in terms of increasing survival rates and reducing infection levels in goldfish (Zhang et al., 2022). It was reported that when the powder of the *Artemisia annua* plant was applied at a concentration of 20 g/kg of feed for 45 days, it provided strong protection against the *I. multifiliis* disease in goldfish, reduced the infection rate, and increased the fish survival rate by 30% compared to control (Wu et al., 2017).

Trichodinosis is a disease caused by ciliate protozoans, commonly occurring in fish farms and intensive systems when fish are exposed to stress and high stocking densities. The *Trichodina* species of protozoan is characterized by causing skin and gill damage, decreased growth, increased susceptibility to secondary infections, and death in severe cases (Noga, 2010). It has been reported that *in vitro* trials of raw extracts from garlic (*A. sativum*) and Indian almond (*T. catappa*) at a dosage of 800 mg/L for 2 days per bath killed 100% of *Trichodina* protozoans (Chitmanat et al., 2005).

The application of green tea (*Camellia sinensis*) extract at 0.9% for 5 minutes per bath has been declared to reduce *Trichodina* infestations by 95% in tilapia (*Oreochromis niloticus*) hatcheries (Noor El-Deen, 2010). The use of three different bioactive alkaloids produced from the plant *Chelidonium majus* (chelidonine 1.0 mg/L for 48 hours per bath, chelerythrine 0.8 mg/L for 48 hours per bath, and sanguinarine 0.7 mg/L for 48 hours per bath) has been declared to prevent 100% of *Trichodina* infections in *Parabramis pekinensis* fish (Yao et al., 2011b).

It was recorded that crushed garlic (*A. sativum*) at 300 mg/L and garlic oil at 3 g/L reduced infections by 23% and 13%, respectively, in Trichodina-infected tilapia fry compared to the control group (Abd El-Galil & Aboelhadid, 2012). A study in goldfish (*C. auratus*) recommended incorporating mahogany (*Swietenia mahagoni*) powder at a diet dosage of 8 g/kg/day for 5 days and Indian bay leaf (*Cinnamomum tamala*) powder at dosages of 4-8 g/kg/day for 15 days to completely eliminate trichodinid ciliates (Saha et al., 2020). Garlic (*A. sativum*) and Sheh el-baathran (*Artemisia judaica* as a traditional Egyptian medicinal plant), in their ground dry forms, added to formulated diets of tilapia (*O. niloticus*) at a rate of 1 g/kg for 15 days, completely ended *Trichodina* ciliate infection and reduced the mortality rate of tilapia fish (Aboud, 2010).

Parasites belonging to the *Hexamita* genus are a group of flagellated protozoa that live freely in both freshwater and saltwater environments. Most protozoal *Spironucleus* species reside in the intestines and gall bladders of fish (Moon et al., 2006). It has been indicated that the essential oils from *Lavandula angustifolia* and hybrid lavender as lavandin (*L.* x *intermedia*) used at concentrations of 1% and 0.5% respectively for 30 minutes, show complete effectiveness against *Hexamita inflata* infections.

Furthermore, Ajoene oil derived from A. sativum has been recorded to inhibit *Sprionucleus vortens* (syn: *Hexamita*) trophozoites found in the feces of freshwater angel fish (*Pterophyllum scalare*). The minimum inhibitory concentration (MIC) of Ajoene oil in laboratory tests (*in vitro*) is reported to be 40 µg/mL. Additionally, it has been emphasized that Ajoene oil acts in synergy with metronidazole (4 µg/mL MTZ), reducing the MIC level by 16 times. Researchers have shown the potential of Ajoene oil as an alternative therapeutic agent in the treatment of hexamitosis, a significant infection in angel fish (Williams et al., 2016).

The *Piscinoodinium* genus of protozoan (dinoflagellate) parasites is a freshwater equivalent to the pathogenic *Amyloodinium* genus in marine fish. Particularly, disease cases caused by *Piscinoodinium limneticum* in ornamental species have frequently been reported from North America, and problems caused by *P. pillulare* from Europe (Noga, 2010). It has been reported that Tambaqui fish (*Colossoma macropomum*), a commercially valuable edible fish species infected with *P. pillulare*, could be treated with *Mentha piperita* (peppermint) essential oil at a concentration of 40 mg/L for 3 days, with 10-minute baths at 24-hour intervals, showing anti-

Piscinoodinium efficacy of 79.91% in body mucus and 54.56% in gills (Ferreira et al., 2019).

In recent years, herbal therapeutic compounds have been used on ectoparasitic protozoans infecting teleost fish (e.g., *Ichthyophthirius* and *Trichodina*). It is known that protozoan ectoparasites more frequently cause diseases in the gills and skins of freshwater fish compared to marine fish (Rohde, 2005; Woo, 2006).

Recently, some studies have encountered the use of plant-derived compounds to control and prevent marine ciliate species such as *Cryptocaryon irritans* (Zhong et al., 2019) and *Scuticociliates* sp. (Harikrishnan et al., 2010, 2011b, 2012). Plant-based compounds have started to show promise in treating infections caused by protozoan pathogens in fish through these scientific studies, opening a discussion on artificial chemical and drug applications in modern aquaculture and even starting to offer a safer and more sustainable alternative solution (Li et al., 2022; Reverter et al., 2014; Valladão et al., 2015; Wunderlich et al., 2017). Extracts derived from medicinal plants have been used to treat *Enterocytozoon hepatopenaei* (EHP), a protozoan parasite causing severe pathological damage and economic losses in shrimp farming (Rajendran et al., 2016). In one of the few studies regarding the use of medicinal plants in the treatment of shrimp protozoan diseases (as mentioned in Table 1), supplementation with allicin in the feeds of shrimp against Gregarines sporozoites was tested, however, it was stated that the sporozoites were not completely eradicated from the white shrimp (*Lithopenaeus vannamei*) digestive tract (Maduri et al., 2021). Despite the presence of severe infectious diseases in mollusc culture, especially *Mytilicola intestinalis*, *M. orientalis*, *Urastoma cyprinae*, and *Parvatrema duboisi* from the Mediterranean mussel (*Mytilus galloprovincialis*) (Yılmaz et al., 2020) and diseases caused by *Marteilia refringens* and *Bonamia* sp. (Alcivar-Warren et al., 2023), and *Perkinsus marinus* (Andrews, 1996) in oyster culture, there are still no plant-based compound applications aimed at their treatment.

Considering the potential for molluscs to be grown in hatchery conditions and closed-circuit system cultivation conditions under full control, as well as commonly being farmed in open sea, it is believed that phytochemicals derived from medicinal plants could find use against parasites in molluscs as phytotherapeutic agents. Given that invertebrates such as mussels, oysters, shrimp, crayfish, and lobsters, unlike vertebrates, usually do not have acquired immunity and must rely on innate immune systems to protect against infections, it is considered that plant extracts could benefit in generating appropriate immune responses for healthy growth in aquaculture. At this point, more research is needed to explore the potential of using natural remedies to combat parasites in shellfish aquaculture.

Research gaps, conclusions, and future perspectives

The integration of plant compounds into aquaculture operations signifies a burgeoning trend driven by a collective acknowledgment of their sustainability and environmental advantages. Beyond their conventional role as anti-parasitic agents in aquaculture, these compounds boast numerous benefits, including stimulating growth, enhancing immunity, and possessing potent antibacterial properties. Moreover, their versatility in serving as anaesthetic agents during fish handling and transportation underscores their value in promoting humane practices within aquaculture operations (Bulfon et al., 2015; Dawood et al., 2021; Vijayaram et al., 2023).

While recent research has shed light on the effectiveness of plant-derived compounds in combating protozoan parasites in finned fish farming, investigations into their efficacy in shellfish farms are notably deficient and necessitate immediate attention. Despite ample data showcasing the potential benefits of medicinal plants in enhancing fish farming, the limited availability of commercial products impedes their widespread adoption in the industry. Encouraging the development of large-scale herbal solutions for both finned fish and shellfish emerges as a critical step in bridging this gap. Additionally, the abundance of medicinal plants across various regions presents an untapped resource to optimize fish production, yet farmers often lack awareness of their potential contributions. To address these challenges, collaborative efforts must be coordinated among researchers, laboratories, aquaculture associations, cooperatives, and government agencies. By promoting synergy and facilitating information exchange, stakeholders can raise awareness among local farmers about the efficacy of native herbal plants in aquaculture environments. Such concerted efforts not only promote sustainable practices but also empower farmers to maximize production while minimizing negative environmental impacts, thus charting a course towards a more resilient and responsible aquaculture industry.

Furthermore, the pursuit of sustainability in aquaculture necessitates prioritizing responsible agricultural practices that uphold ethical standards. This includes minimizing the use of artificial chemicals and supporting the well-being of aquatic organisms. Aquaculture operations can ensure the humane treatment of fish and shellfish by prioritizing animal welfare and minimizing stress during handling and transportation. Moreover, responsible aquaculture extends beyond immediate operational practices to include broader considerations such as biodiversity conservation and habitat protection. Aquaculture efforts can coexist harmoniously with surrounding ecosystems by adopting habitat-friendly farming techniques and implementing measures to reduce the risk of pollution and habitat degradation.

Ethical considerations also encompass the welfare of workers in the aquaculture industry. Ensuring fair labour practices and providing adequate training and support to workers contribute to developing a culture of responsibility and accountability in the industry. Ultimately, maintaining environmentally friendly approaches and responsible aquaculture practices underscores a commitment to

environmental stewardship and ethical behaviour. By adopting sustainable alternatives, promoting animal welfare, and keeping ethical considerations at the forefront, the aquaculture industry can strive towards a future that is both environmentally conscious and socially responsible.

AUTHOR CONTRIBUTION

All authors contributed to the study idea and design. The writing and editing of the article were done by the names listed above, and all authors have read and approved the article.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

ETHICAL APPROVAL

No specific ethical approval was required for this study.

DATA AVAILABILITY

Data supporting the results are available in the review manuscript.

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