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Assessment of chemical risks and benefits connected with macroalgae consumption

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Abstract

Reducing animal-based food production and consumption due to environmental issues and undergoing upcoming changes in food dietary patterns is pushing European society to search for new protein sources. Consuming macroalgae (seaweed) is one of the possible solutions, and it is an exciting alternative for both sustainability and consumers' health. The aim of this work, implemented under the EU-FORA fellowship programme, was to evaluate the current and projected consumption of macroalgae in terms of possible beneficial and detrimental effects on consumers. The risk–benefit assessment methodology was selected as a tool for this task, and a broad range of qualitative analyses of raw material composition (e.g. fatty acids, micro-, macroelements, heavy metals, biogenic amines). The current levels of macroalgae consumption in the EU are deficient; therefore, alternate scenarios using data from other countries and substitution scenarios are needed. Iodine turned out to be the most pivotal constituent – on the one hand; it is an element essential for life, often fortified in foods like milk or salt; on the other, its overdosing leads to serious thyroid complications. A very high variance in iodine levels between algal species was observed; therefore, it was suggested that this valuable knowledge is helpful in dietary recommendations.

KEYWORDS

dietary shift, EU-FORA, food safety, iodine, risk–benefit assessment, seaweed

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1 | INTRODUCTION

Since 2017, the European Food Safety Authority (EFSA) has organised annual European Food Risk Assessment (EU-FORA) fellowship programmes. The initiative aims to strengthen the European network of food safety assessment experts and involve all the Member States of the European Union (EU) in risk assessment tasks organised and coordinated by EFSA. Implementing this year-long programme includes a scientific internship (usually 3 to 5 months long) in the hosting organisation and 7 weeks of training organised by EFSA both remotely and in its premises in Parma.

One of the fellows of the EU-FORA seventh cohort (2023–2024) was Dr. Łukasz Woźniak from the Institute of Agricultural and Food Biotechnology (IAFB) in Warsaw, Poland, who worked on the 'Assessment of chemical risks and benefits connected with macroalgae consumption' under supervision of Prof María Soledad Prats Moya from University of Alicante (UA) in Spain.

Macroalgae, often called 'seaweed', are a broad group of multicellular marine plants. They are typically divided into three main groups due to their physical properties: red algae (*Rhodophyta*), brown algae (*Phaeophyta*) and green algae (*Chlorophyta*). Their wild production is usually considered sustainable and environmentally friendly as it does not require fresh water, fertilisers or pesticides. Currently, the most extensive consumption of macroalgae is reported for the East Asia region; however, as it is a good source of high-quality protein, an increase in its production and worldwide consumption might be an excellent method to combat global food security issues (Rawiwan et al., 2022). Moreover, consumers' attitudes towards seaweed are positive, contrasting with other novel food sources such as insects or cultured meat (Govaerts & Olsen, 2023). Apart from direct consumption, the algae can also act as a source of bioactive and functional compounds, including polysaccharides, antioxidants, carotenoids and microelements (Kumar et al., 2021; Xie et al., 2023).

2 | DESCRIPTION OF THE WORK PROGRAMME

2.1 | Aim

This work aimed to evaluate the impact of macroalgae consumption in terms of possible beneficial and detrimental effects on consumers. The research focused on the algae's chemical constituents – the possible microbial contamination of the products was not within the scope of work.

The abovementioned impact of macroalgae was verified by selecting and analysing several chemical constituents according to the previous information from the literature. Among the beneficial compounds, unsaturated fatty acids and essential micro- and macroelements were selected, while heavy metals, biogenic amines and polycyclic aromatic hydrocarbons (PAHs) were chosen as the most significant hazards. Additionally, due to scarce data on the current consumption of algae in EU countries, it was necessary to employ some hypothetical scenarios using data from other countries and substitution scenarios.

2.2 | Methods

The research materials were 26 samples of macroalgae bought from European producers. The samples belonged to nine species of algae and were obtained from aquaculture and wild habitats in Atlantic Ocean; all the samples were collected in autumn of 2023. The samples were freeze-dried prior to further handling.

The analytical part of the work included a range of quantitative analyses of algae. The mercury content was quantified using the dedicated detector, while levels of 31 other elements (including heavy metals, micro- and macroelements) were measured with the inductively coupled plasma–mass spectrometry (ICP–MS) technique. The content of biogenic amines and polycyclic aromatic hydrocarbons was established using liquid chromatography–mass spectrometry (LC–MS). The levels and patterns of fatty acids were measured using gas chromatography with MS detection utilising fat extracts obtained using the Folch method. Apart from using the data obtained in the project, the available literature data on levels of the abovementioned compounds in algae was used; this includes a recent assessment on levels of heavy metals in algae and halophytes performed by EFSA (EFSA, 2023).

The consumption data for EU countries was obtained from the resources available on the EFSA website. The algal products are among the groups in the FoodEx2 food classification standard. The data on algal consumption in other countries (Japan, South Korea) was acquired from official databases maintained by local authorities. Additionally, substitution scenarios were analysed to assess the effect of substituting, e.g. leafy green vegetables with similar quantities of seaweed.

The risk–benefit assessment was selected as an appropriate evaluation method for the impact of macroalgae on diet. This method is supported by EFSA, which prepared guidance on its use and its recent update (EFSA, 2010; EFSA, 2023; EFSA, 2024). The literature provides examples of the utilisation of this method, including some conducted in previous editions of the EU-FORA programme (Garciarena et al., 2022; Mihalache et al., 2022). The reports often show the main problem of the method – transforming the presence of beneficiary compounds into measurable beneficial health effects (Berija et al., 2012; De Cock et al., 2023; Nøstbakken et al., 2021).

2.3 | Results

The levels of 'the main four' heavy metals (arsenic, lead, cadmium, mercury) did not significantly threaten health at the current consumption levels. Notwithstanding, the projected increased consumption could pose a threat, especially in the case of cadmium and arsenic. Therefore, in future, it could be reasonable to establish legal limits for those elements in algal products.

The more pivotal results were obtained for iodine. In this case, the levels were very high due to bioaccumulation and considerable variability between algal species was observed. On the one hand, iodine consumption is essential for life, often fortified in foods like milk or salt. On the other hand, overdosing leads to serious thyroid complications. Therefore, it was suggested that this knowledge be used in dietary recommendations to protect consumers from species with very high levels and promote those with moderate levels.

Algae also turned out to be a possible source of other necessary nutrients – the levels of magnesium and potassium can be considered significant from a dietary point-of-view, even considering low intake.

The content of other quantified contaminants (biogenic amines) and PAHs was too low to threaten consumers' health, even considering increased consumption scenarios. A similar situation was observed in the case of fatty acids; their composition was nutritionally interesting, with a significant content of unsaturated ones, but their total content in the sample was not high enough to significantly affect.

2.4 | Further research

Apart from the analytical tasks connected with food risk–benefit assessment, the fellow also conducted others meant to understand better macroalgae properties and their possible impact on human health.

The total protein level in the samples was determined using the Dumas combustion method with a total carbon and nitrogen analyser. The conversion factor 4.92 was used instead of 6.25, typically used in general calculations (Limiñana et al., 2023).

The antioxidative activity of macroalgae was assessed using three chemical assays that are very often used. Two of the assays relied on the scavenging of artificial free radicals (ABTS and DPPH). The last method was designed to estimate total content of phenolic compounds (TPC), but due to low selectivity is often treated as another method of measuring antioxidative features (Nur Alam et al., 2013).

Additionally, the bioaccessibility of the selected heavy metals, micro- and macroelements, was evaluated in vitro. The standardised INFOGEST protocol was selected as a well-known and validated method of simulating human gastrointestinal tract processes. It included three phases (oral, gastric and intestinal) and used the conditions of digestion (temperature, pH, presence of enzymes and their cofactors) as close to in vivo as possible (Minekus et al., 2014).

3 | OTHER ACTIVITIES

Dr. Woźniak, along with five other fellows, took part in the meeting organised by the Spanish Agency for Food Safety and Nutrition (Agencia Española de Seguridad Alimentaria y Nutrición; AESAN) on the 27 and 28 February 2024. During the first day, the fellows visited AESAN headquarters in Madrid and had an opportunity to familiarise themselves with the goals, scope of work and structure of this organisation and present themselves and their EU-FORA projects. The second day's main activity was visiting the National Food Centre (Centro Nacional de Alimentación; CNE) in Majadahonda, Madrid. During the stay, the fellows could explore the laboratories dealing with different aspects of food safety (e.g. chemical contaminants, microbiology, food contact materials, parasitology) and exchange their knowledge and experience with staff members.

From the 16 to 18 September 2024, the fellow will participate in the 30th Polish Bromatology Symposium (XXX Ogólnopolskie Sympozjum Bromatologiczne) that will take place in Gdańsk, Poland. He will present the conference speech entitled 'Benefits and risks connected with macroalgae consumption' ('Korzyści i zagrożenia związane z konsumpcją makroalg') summarising the main findings of his research.

Additionally, during his stay at the University of Alicante, Dr. Woźniak took the role of the co-supervisor of the final degree project of one of the students. The work entitled 'Evaluation of nutritional risks and benefits of the consumption of macroalgae such as *Ulva lactuca*' ('Evaluación de riesgos y beneficios nutricionales del consumo de macroalgas como *Ulva lactuca*') has been defended by Ana Delicado García on 11 June 2024.

4 | PARTICIPATION IN EU-FORA PROGRAMME

As of the end of August 2024, seven editions of the EU-FORA programme changed the food risk assessment landscape in the EU, supplying the professional community with over a 100 graduates equipped with the tools and expertise necessary to support the goals of EFSA and local food safety authorities. The programme action is not limited to its official duration as networking between fellows leads to subsequent frequent scientific activities, including the EU-FORA Alumni initiative.

From a fellow's point-of-view, participation in the programme is an excellent opportunity to improve their proficiency in food safety. The training modules supply fellows with immense knowledge of legal and procedural approach to this subject, while visiting the hosting site is an invaluable chance to collaborate with leading scientific experts from foreign organisations.

5 | DISCLAIMER

The precise results of the risk–benefit assessment are intended for publication in a separate journal paper. Therefore, only a brief description of the results was presented here to avoid copyright violation.

ABBREVIATIONS

AESAN	Spanish Agency for Food Safety and Nutrition (Agencia Española de Seguridad Alimentaria y Nutrición)
CNA	National Food Centre (Centro Nacional de Alimentación)
EFSA	European Food Safety Authority
EU-FORA	European Food Risk Assessment Fellowship Programme
IAFB	Institute of Agricultural and Food Biotechnology (Instytut Biotechnologii Przemysłu Rolno-Spożywczego)
ICP-MS	inductively coupled plasma–mass spectrometry
LC–MS	liquid chromatography–mass spectrometry
PAHs	polycyclic aromatic hydrocarbons
TPC	total phenolics content
UA	University of Alicante (Universidad de Alicante)

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