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Dietary Fiber in Preventing Non-Communicable Diseases: Predicting Prevented Deaths and Economic Impact through the Use of Algae as a Fiber Source

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Abstract

Non-communicable diseases (NCDs) are responsible for two-thirds of premature deaths in Europe. This added to the European socio-economic scenario already weakened by the vital

aging of the population, contributes to the loss of active individuals, weakening competitiveness and social and economic sustainability, thus making the prevention of NCDs a European objective. Preventing NCDs with the enrichment of the food environment using algae or their compounds, which are rich in nutrients and bioactivities, is an excellent way to promote healthy eating of ecological and sustainable foods. This strategy generates social, economic, and environmental gains, as well as improvements in health and sustainability. The objective of this study was to verify whether the intake of the recommended dose of fiber caused a decrease in the number of deaths caused by NCDs. The NCD prime scenario modelling tool was populated with demographic data on mortality and food intake for 2016. The results obtained by applying the NCDprime model suggested that with the recommended fiber dose, 4.5% of deaths were averted, and about 30 million euros were saved. The number of prevented deaths and the potential for cost savings represent significant health and economic gains. It will allow, in the future, new health policies to be equated with an adaptation of the food ecosystem and the development of new functional foods.

Keywords
Algae; dietary fiber; NCDprime; non-communicable disease; dietary habits; socioeconomic factors

1. Introduction

Non-communicable diseases (NCDs) pose a significant health burden and are responsible for a majority of premature deaths in Europe [1, 2]. The socio-economic landscape in Europe is further strained by the aging population, leading to the loss of active individuals and impacting competitivenesssocial and economic sustainability [3, 4]. In light of these challenges, NCD prevention has become a critical objective for European countries [4, 5]. One promising approach to address this issue is the enrichment of the food environment with algae or their compounds, known for their rich nutrient content and bioactivities [6]. This strategy promotes the consumption of healthy, ecological, and sustainable foods, generating health benefits and social, economic, and ecological gains [7-10].

In this study, we aimed to investigate whether meeting the recommended dietary fiber intake could lead to a reduction in NCD-related deaths [11]. Fiber is known for its numerous health benefits, including its positive impact on various NCDs [12, 13]. To assess the potential effects, we utilized the NCDprime scenario modeling tool, which integrated demographic data on mortality and food intake for 2016 [14, 15]. By analyzing the data and applying the NCDprime model, we aimed to quantify the effects of achieving the recommended fiber intake on NCD-related mortality.

Modifying the food environment through functional foods is an excellent strategy to obtain economic and health benefits. If these benefits, combined with seaweed's economic and environmental benefits, lead to the search for seaweed fiber sources [16-19]. The hypothesis that seaweed can be used as a source of fiber is based on epidemiological evidence observed in Asian countries. In these countries, where seaweed consumption is high, there is a reduced prevalence of cardiovascular diseases [20]. The nutritional richness of macroalgae is supported by the evidence

due to the presence of bioactive compounds, vitamins, minerals, and fiber, which offer numerous benefits to human health [21].

One of the seaweed with many benefits is the carrageenans found in the walls and intercellular spaces of the algae Chondrus crispus, belonging to the phylum Rhodophyta, which have the property of gelling, thickening and stabilizing aqueous solutions without altering their color and flavor [22, 23]. They are also inexpensive. Because of these properties, carrageenans are widely used in the food industry and have been validated by the European Union [24]. They are identified on labels under the food additive code E407 [24-26].

The extensive use of carrageenan in various food items, beverages, and other products has prompted numerous studies to ensure food safety and highlight the benefits of its consumption. As a result, research has focused on carrageenan as a source of fiber [16, 22, 24]. The hypothesis of using carrageenan as a source of fiber to fortify the food environment is an excellent option, given the ease with which it can be used to fortify foods with fiber, the guarantee of its safety for human consumption, the numerous human health benefits that have already been observed as a result of its consumption, and its ecological potential [16, 17, 21].

This study contributes to the growing body of evidence supporting the importance of dietary habits in preventing NCDs. Highlighting the effect of fiber intake on reducing NCD-related deaths and the associated economic benefits underscores the need for focused interventions and policy measures in promoting healthy dietary choices. These findings pave the way for future research and actions aimed at aligning health policies with the transformation of the food environment, ultimately fostering improved health, sustainability, and well-being.

2. Materials and Methods

The NCD prime modulation tool was used to examine the effect of alterations in dietary habits on the incidence of deaths resulting from NCDs. The modulation-free tool NCDprime, developed and provided by the World Health Organization (WHO), was used to study the number of deaths that could be prevented by implementing health-promoting consumption of the recommended daily dietary fiber intake.

The study presented here applies the NCDprime tool to verify whether ingesting the recommended dose of fiber reduces the number of deaths from NCDs. The quality of the obtained results is directly linked to the data provided to the model. Therefore, the data used to populate the model is below. To enhance result certainty, we collected and statistically analyzed 20 simulation results.

For the same purpose, population data from the National Statistics Institute (INE) for 2016 were used, as well as dietary data from the National Survey on Diet and Physical Activity (IAM-AF), collected between September 2015 and September 2016. Data on mortality in the Portuguese population in 2016 were obtained using the Global Health Data Exchange tool, IHME.

The data obtained from the model were treated statistically, allowing to create three age groups: young (15-19 years old), adult (20-64 years old), and elderly (≥65 years old) [3, 27], see Table 1. Once the 20 simulations had been performed and the data collected, the data were statistically processed using the Statistical Package for the Social Sciences (SPSS, IBM, version 28, for Windows). Descriptive and inferential statistics were used. The results are presented as mean ± standard deviation, rounded to one decimal place.

Table 1 Sample Characterization.

Sex / Age	Woman	Men	Total
15-19	273725	285539	559264
Young people	273725	285539	559264
20-24	267677	274167	541844
25-29	277226	277458	554684
30-34	321499.5	305934	627434
35-39	388286.5	358175	746462
40-44	422322	387083.5	809406
45-49	394938	361957.5	756896
50-54	397944	359277.5	757222
55-59	373651	335611	709262
60-64	348418.5	304205.5	652624
Adults	3191962.5	2963869	6155834
65-69	324480.5	275790	600271
70-74	283280.5	221160.5	504441
75-79	250021	180312.5	430334
80-84	211199.5	132988.5	344188
85+	190381	89118.5	279500
Elderly	1259362.5	899370	2158734
Total	**4725050**	**4148778**	**8873828**

To obtain the value of the savings inherent in the number of deaths avoided, the study by Costa and his collaborators was considered. They calculated the costs associated with atherosclerotic events in the Portuguese population [28]. The formula used is the cost estimated for "non-participation in the labor market" multiplied by the percentage of deaths avoided in the adult age group. This allows the economic value saved to be estimated from the number of lives saved.

3. Results

Applying the criteria previously presented in the methodology, a sample of 8.87 million individuals was obtained. The persons eligible for the analysis are grouped by age every 5 years, the first group being those aged 15 to 19 and the last group being all persons aged 85 and over, then grouped into three age groups: adolescents, adults, and elderly, see Figure 1.

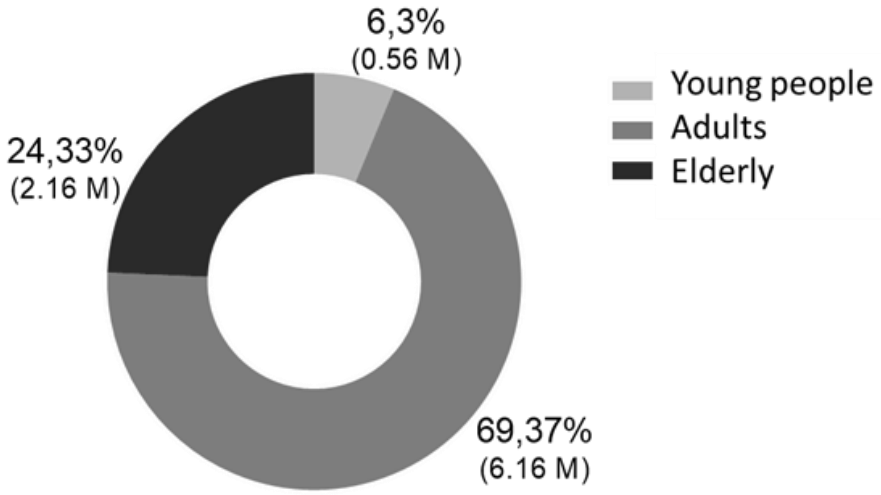

Figure 1 Sample distribution by age groups.

By analyzing the dietary data collected in the IAM-AF, it was possible to verify that the daily intake of dietary fiber in Portugal is below the recommended value. When analyzing the intakes by sex and age group, it was verified that dietary fiber intake was reduced by between 22% and 45% in women and between 35% and 54% in men, as shown in Figure 2.

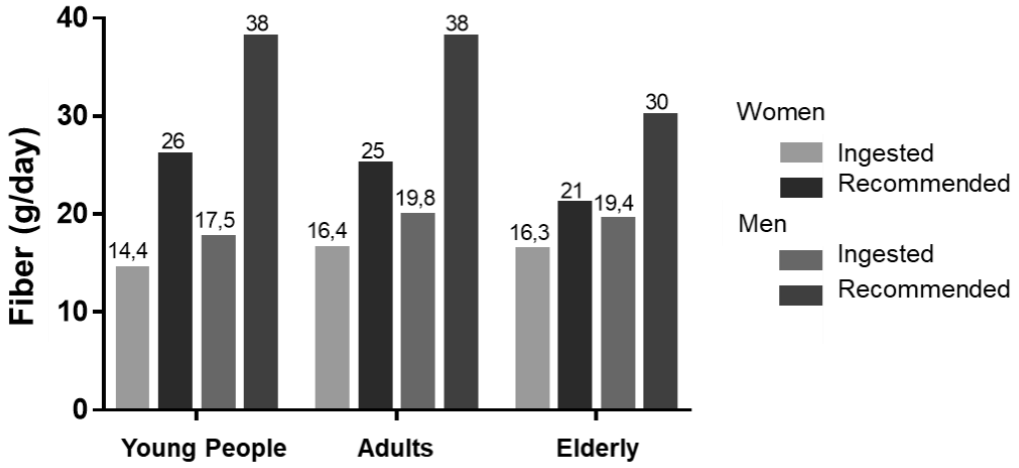

Figure 2 Fiber intake by sex and age group.

Using the NCDprime prediction model, it was possible to estimate that if the Portuguese population consumed the reference daily fiber intake, the number of deaths prevented in 2016 would be 4.546 ± 1.044, i.e., less than 4.48% of deaths in the total national population.

Analyzing the data by gender, the number of deaths from NCDs among men in 2016 was 49.069. According to the data obtained in the counterfactual model, where the population consumes the recommended dose of fiber, the number of deaths was 46.051 ± 702.3, indicating a potential reduction of 3.018 ± 702 deaths, or 6.15%.

Regarding the results observed for women, it was found that the trend was maintained, with 52.508 deaths in the factual group and 50 deaths in the counterfactual group with daily intake of

the recommended dose of fiber. 980 ± 349 deaths and it can be concluded that 1.528 ± 349 lives can be saved, i.e., a 2.91% reduction in fatalities, see Figure 3.

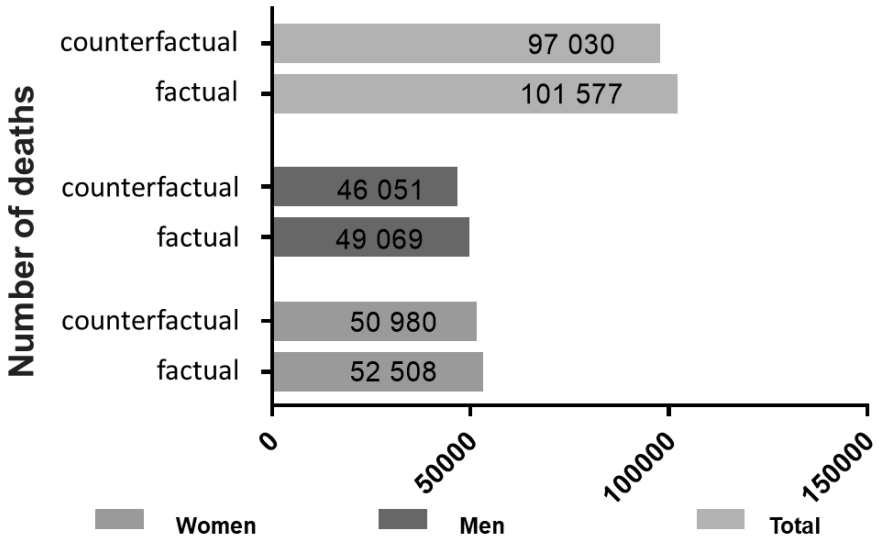

Figure 3 Number of deaths by scenario and by sex.

If we analyze only the data relating to the adult age group, i.e., those aged between 20 and 65, we can see that the number of deaths among women has fallen by 75 ± 14, i.e., by 1.9%. The analysis of the male results shows a reduction of 453 ± 103 deaths, i.e., a 5% reduction in the fatalities suffered by the male population aged between 20 and 65. In other words, there is a 4% reduction in deaths in the adult age group because of the inclusion of fiber in the diet.

Applying the formula cost of "non-participation in the labor market" multiplied by the percentage of deaths averted in the adult age group, we obtain:

Cost of "non-participation in the labor market" in euros multipled by the percentage of deaths prevented in the adult age group = Value saved in euros

$$738306327€ \times 0.04 = 29532253.08€.$$

This corresponds to a saving of 29532253 euros in 2016.

4. Discussion

Applying NCDprime's predictive model, we demonstrated that consuming recommended dietary fiber could bring health and economic benefits to Portuguese society. It was estimated that 4.546 ± 1.044 deaths could be averted, representing a reduction of 4.5%, by promoting dietary fiber intake in the Portuguese diet. Comparing the results obtained with the available literature, the study seems to follow the trend found in previous studies. According to Chuwa et al. [11], a high-fiber diet prevents the development of NCDs, namely cardiovascular diseases (CVD), colorectal cancer, and metabolic syndrome (MS).

In the study developed by Ioniță-Mîndrican and collaborators [29], the number of deaths prevented was 27% of the number of deaths caused by coronary disease, which represents a higher

number of deaths prevented compared to the data obtained in the present study [29, 30]. The differences observed can be explained by the sample studied since the survey carried out by Ioniță-Mîndrican took into account results obtained in the American population, where fiber intake is lower than in Portugal [31].

The results obtained by applying the NCDprime prediction model to the results presented in the study by Costa et al. allow us to conclude that the reduction in the number of deaths observed in the adult age group will have a direct economic impact [5]. The number of deaths prevented in the adult age group has a direct effect on the costs associated with non-participation in the labor market [7]. Thus, a 4% reduction in the number of deaths in the adult age group would save €29532253 by fortifying the diet with fiber.

The number of deaths prevented is associated with a reduction in the number of events and a decrease in the risk of developing pathologies so that the prevalence is also reduced, which allows us to conclude that the direct socio-economic benefits will be greater than those presented and will have an impact on the competitiveness of the national economy [32, 33]. According to the study carried out by Costa et al. in Portugal in 2016, diseases of atherosclerotic origin accounted for 1% of the gross domestic product and 11% of current health expenditure [28]. In light of the above, there is a need to promote dietary fiber consumption to free up economic and human resources invested in monitoring, treatment, and expenditure due to the high prevalence of NCDs [4].

The importance of combining the expected health, economic, and social benefits with sustainability leads to the conclusion that incorporating seaweed as a source of dietary fiber in the diet of individuals represents an efficient way to achieve more socio-economic benefits [18, 34, 35]. Algae and their constituents, such as carrageenans, represent a strong candidate as a source of dietary fiber, as they not only provide direct health benefits due to their biopotential and dietary fiber richness but are also an attractive choice from an environmental point of view [8-10, 17]. In Portugal, due to the wide availability of seaweeds along the national coast, they are easy to obtain, making dietary fiber enrichment a realistic choice [16].

One of the components of seaweed that already has defined properties and benefits for developing foods fortified with seaweed and its components is carrageenan [17]. Carrageenans are found in the walls of algae and are widely used in the food industry. Studies have demonstrated their potential to regulate lipid profile and play a preventive role in CVD, opening the door to using this component in functional foods [16, 36]. The knowledge of the potential of seaweed and its constituents as antioxidants, antitumors [37], anti-lipid [17, 36, 38], anticoagulant [21, 37], antifungal, immunosuppressant, antiviral and support of digestive health [21] allows to expect high health benefits from its association with food [10].

The health-promoting properties of seaweed and the knowledge that its consumption is safe allow a high degree of freedom in developing policies to enrich the diet with fiber through its use [39]. However, despite the numerous benefits associated with the consumption of seaweed, there is resistance to its consumption among the population; according to the research carried out by Duarte, 2018, it was found that 41.8% of Portuguese claim to have never consumed seaweed, showing little interest in introducing these foods as a replacement for traditional protein sources [6]. According to what was observed in the study carried out by Salgado et al., 2019, one of the ways to introduce seaweed and its components into the diet is by incorporating them into the composition of already existing and widely consumed foods, thus more easily overcoming the cultural barriers [6, 10].

Awareness of the importance of creating solutions that provide health, economic, and social benefits and sustainability led to the development of the "alga4food" project in Portugal. The project aims to facilitate the incorporation of seaweed into individuals' regular diets by developing food products with seaweed in their composition, thus promoting the consumption of functional foods that are beneficial to health [10, 39]. The combination of the knowledge of the inherent advantages of enriching food with fiber, with the benefits of using seaweed as a source, added to existing projects already in the national territory and the existence of good examples of national health policies [40-42], lead to the desire that the development of health policies to promote changes in the food environment becomes a reality [42].

In Portugal, other nutritional environment intervention projects have been developed and translated into health policies, such as the minorsal.saude project [40, 41] and the introduction of the special tax on sugary drinks [42] have produced good results, enabling the Portuguese to reduce their salt and sugar intake without changing their behavior. In this way, Portugal seems to be equipped with the necessary tools to develop a health policy that, following the good examples of previous policies and involving new partners to respond to new knowledge and challenges, will make it possible to reduce the number of deaths from NCDs and thus reduce their socio-economic impact through the introduction of more nutritious and sustainable foods.

During the development of this study, limitations were identified due to the use of a modulation tool. These limitations restrict the predictive power of the model and the number of model interferences. Additionally, using only 20 exceptions for subsequent statistical treatment may pose limitations. Furthermore, it was discovered that the results followed a normal distribution, making applying parametric tests impossible. Regarding calculating the economic impact, the main limitation was the scarcity of studies on the cost of treating the pathology in Portugal. This may result in an underestimation of the savings, as it only considers the value associated with the number of deaths avoided in adults with colorectal cancer rather than the total number of deaths avoided. It is important to note that this calculation does not include the value associated with the number of deaths avoided. One of the challenges encountered was the absence of research on the efficacy of seaweed in preventing fatalities from the group of illnesses being investigated.

It would be advisable for future researchers to carry out a more significant number of replications of the prediction model so that more powerful statistical tests can be used to obtain more robust results. The calculation of the saved resources in terms of the number of deaths prevented, considering all the age groups presented in the study. It would be interesting to demonstrate the savings according to pathology, thus allowing a better verification of the impact of fiber enrichment on the diet. Another important step would be to calculate the costs associated with dietary fiber enrichment with seaweed and its constituents, such as carrageenans, to verify the cost-effectiveness of the intervention.

5. Conclusions

In this way, it would be possible to verify whether the hypothesis of developing a public health policy aimed at dietary fiber enrichment would bring health and economic benefits.

The development of this theme could lead to the design of a health policy aimed at changing the food environment and enriching the diet with fiber through seaweed and its constituents.

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Author Contributions

MP: Conceptualization, Investigation and Writing-original draft. AV: Conceptualization, Investigation, Validation and Writing-review. PA: Conceptualization, Investigation, Validation and Writing-review. LP: Writing-review & editing, Supervision. All authors read and approved the submitted version.

Competing Interests

The authors have declared that no competing interests exist.

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