

Article

Comprehensive Characterization of the Algarve Octopus, *Octopus vulgaris*: Nutritional Aspects and Quality Indexes of Lipids

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Abstract

The common octopus (*Octopus vulgaris*) supports one of the most valuable small-scale fisheries in Portugal, particularly in the Algarve region, with substantial socioeconomic implications. This species holds significant potential for human consumption due to its low lipid content, favorable fatty acid profile, high-quality protein, and essential microelements. This study aimed to provide a comprehensive characterization of octopus specimens landed in two key Algarve fishing areas—Barlavento/Windward (Alvor Harbour) and Sotavento/Leeward (Fuzeta Harbour). We assessed their nutritional value, focusing on protein quality, lipid indexes, trace minerals, and essential vitamins, as well as overall safety and quality. All regulated contaminants and additional potential risks were also evaluated, yielding fully satisfactory safety results. The research was conducted within the framework of the European Sea2See project, which aims to enhance consumer trust and acceptance of sustainably harvested or farmed seafood in Europe. Our findings demonstrate that Algarve octopus is a nutritionally rich seafood product, promoting cardiovascular health and general well-being.

Keywords: nutritional value; *Octopus vulgaris*; lipids quality; amino acids; Fisher ratio; micronutrients; protein efficiency ratio



Academic Editors: Małgorzata Ziarno and Roberta Foligni

Received: 15 May 2025

Revised: 2 July 2025

Accepted: 8 July 2025

Published: 24 July 2025

Citation: Cabado, A.G.; Costas, C.; Baptista de Sousa, D.; Pontes, J.; Rangel, M. Comprehensive Characterization of the Algarve Octopus, *Octopus vulgaris*: Nutritional Aspects and Quality Indexes of Lipids. *Appl. Sci.* **2025**, *15*, 8235. <https://doi.org/10.3390/app15158235>

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1. Introduction

Octopus is a marine resource of considerable economic and nutritional value as a food product. Within the European Union, the common octopus (*Octopus vulgaris*) is the primary octopus species harvested for commercial purposes [1].

The common octopus's fishery is one of the most important and valuable small-scale fisheries in Portugal and has important socioeconomic implications [2–4]. This fishery uses pots and traps to capture octopus [5,6] and constitutes a particularly relevant activity in the Algarve region, where the largest national fleet dedicated to this resource is settled [2,4]. In this region, the common octopus is the most important species not only in terms of landings but also in terms of first sale value. In 2023, 2,401 tons of octopus were landed at the first auction places of the Algarve, reaching a total first-sale value of 19.5 million euros. This quantity of octopus landings accounted for 38.4% of the total reported catches in Portugal and 40.0% of the total first-sale revenue generated nationwide [7]. The common octopus inhabits continental-shelf waters (0–150 m), occupying rocky, sandy, and seagrass

habitats where it constructs dens for shelter and ambush predation [8,9]. With a short, semelparous life cycle of 12–15 months, individuals mature quickly and reproduce once before dying, typically during spring and summer spawning periods [10]. *O. vulgaris* are generalist predators, feeding on crustaceans, mollusks, and small fish, and playing a key ecological role in coastal marine food webs [11].

As an important component of human nutrition, seafood helps prevent health disorders due to the presence of polyunsaturated fatty acid (PUFA) in the lipid composition. It is known that octopus has potential as a marine resource fit for human consumption with a very low lipid content (less than 2% total lipids) but containing the most important fatty acids. Also, this cephalopod has a high protein content, significant levels of both major and trace minerals, and essential vitamins [12].

Most recent studies on octopus caught in this region focus on the size of the catches and their environmental impact; however, data on the nutritional properties and safety of this resource are scarce and are usually extrapolated from other areas [9,12,13]. In this context, the main objective of this work was to evaluate the nutritional quality of common octopus (*Octopus vulgaris*) from fisheries in the Algarve (south Portugal), with special emphasis on lipid and protein indexes, as well as the content of micronutrients. Knowing the nutritional benefits of cephalopods from this region of Portugal will help promote their consumption and have a positive impact on the fisheries economy. Furthermore, providing analytical and research data on this resource will contribute to the overall growth of the octopus' market [12].

2. Materials and Methods

2.1. Sample Collection and Parameters Analyzed Without Shown Results

Samples were collected by fishers from the small-scale octopus fishing fleet of the Algarve. Two areas of the Algarve were considered for sampling purposes: Barlavento/Windward (samples collected by vessels registered at Alvor harbour) and Sotaventto/Leeward (samples collected by vessels registered at the Fuzeta harbour) and analyzed separately due to the well-known differences in the fishing grounds of the two areas [5,14], with western Algarve more exposed to the Atlantic coast and eastern Algarve to the Mediterranean Sea [15–17]. A total of eight samples (three to four individuals per sample) of octopus were collected every three months in each region, from December 2022 to December 2023, with an approximate weight of 1.5 kg per individual. Octopus were eviscerated and frozen immediately after landing, replicating the common practice of the industry, and shipped properly to prevent defrosting. The analysis was carried out in ANFACO-CECOPESCA laboratories that work under the UNE-EN ISO/IEC 17025:2017 standard [18], and it is accredited by the National Accreditation Entity (ENAC) that is a member of the European Accreditation (EA).

To simplify the understanding of the work and visualize the most relevant results, no values or tables referring to the quality of the octopus have been included. However, all the contaminants established in the legislation were analyzed, as well as those that could be considered a risk. Then, we have analyzed microbiological parameters as total viable count (TVC), Enterobacteriaceae, *Escherichia coli*, *Salmonella* spp., *Vibrio parahaemolyticus*, *V. cholerae* and *V. vulnificus*; chemical contaminants: mercury, cadmium and lead, inorganic arsenic, dioxins, polychlorinated biphenyls (PCBs) and dioxins like PCBs; biogenic amines, histamine, cadaverine and spermidine; nutritional compounds as fatty acids, moisture, proteins, ash, salt, carbohydrates; fresh and quality parameters: trimethylamine (TMA), thio-barbituric acid (TBA), peroxides index, K index and marine biotoxins including, lipophilic, paralytic shellfish poisoning (PSP), amnesic shellfish poisoning (ASP), and tetrodotoxin (TTX). In this context, it is worth mentioning that all contaminants evaluated are either

absent or found in an extremely low concentration and very well below the legislated limit. The results obtained in those parameters that are not regulated were also in all cases below those levels published as a reference in the bibliography.

2.2. Proximal Composition, Minerals, Vitamins and Amino Acids Analyses

Moisture was determined by oven drying at 105 ± 2 °C until reaching constant weight. Total protein content was determined using the Kjeldahl method [19,20], which involves acid digestion in the presence of catalysts and heat treatment. The ammonium ions generated from the organic nitrogen in the sample were captured in a boric acid solution for subsequent volumetric analysis using hydrochloric acid.

Sodium and minerals were analyzed by ICP-MS (Inductively Coupled Plasma Mass Spectrometry): after acid digestion, the sample is introduced into an integrated sample introduction system (ISIS) for nebulization and subsequent transfer to the inductively coupled argon. The ions produced are separated according to their charge/mass ratio and simultaneously detected for more than 70 elements.

The amino acid profile is performed by acid hydrolysis for IC-UV (ISO 13903:2005) [21].

Vitamins were analyzed by LC-FLD: Vit. B1-Thiamin (EN 14152:2014 mod. [22]), B2-Rivoflavin (EN 14152:2014 mod. [22]), B-3-Niacin (EN 15652:2009 [23]), and B6-Piridoxin (EN 14164:2014 [24]); by LC-MS Vit. B5-Pantothenic acid (AOAC 2012,16); by microbiological method—Nephelometry Vit. B8-Biotin (LST AB 266.1,1995) and B9-Folic acid (NMKL 111:1985 [25]); and by LC-UV/DAD Vit. B12-Cyanocobalamin [26].

2.3. Nutritional Quality

In order to evaluate the nutritional quality of octopus, several indicators, such as total proteins, amino acid content, Fischer ratio (FR), and protein efficiency ratio (PER), were estimated.

FR is the molar ratio of branched-chain amino acids (aa) (valine, leucine, isoleucine) to aromatic aa (phenylalanine, tyrosine), as shown in the equation below. It is important for assessing liver metabolism, hepatic functional reserve, and the severity of liver dysfunction [9,10].

$$\text{Fisher Ratio} = ([\text{Val} + \text{Leu} + \text{Ile}]) / ([\text{Phe} + \text{Tyr}])$$

On the other hand, the estimation of protein efficiency ratio (PERest) was calculated based on the amino acid profile according to the following equation [27,28]:

$$\text{PERest} = [0.00632 \times (\text{Ile} + \text{Lue} + \text{Lys} + \text{Met} + \text{Phe} + \text{Thr} + \text{Val} + \text{Arg} + \text{Hys} + \text{Tyr})] - 0.1538$$

The abbreviations correspond to valine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine arginine, histidine, and tyrosine. The amount of amino acids was expressed in g/kg protein.

In order to get more nutrition information on octopus, the amino acid score was estimated. Amino acid score determines how effectively the absorbed dietary nitrogen can meet the requirements of indispensable or essential amino acids (IAAs or EAAs) at the level of protein intake. This parameter is calculated by comparing the content of EAAs in the protein with its content in a reference standard [29]. The following formula is used to calculate this value:

$$\text{AA score\%} = (\text{mg of AA per g of protein}) / (\text{mg of AA in the reference standard}) \times 100$$

2.4. Determination of Fatty Acids Profiles

2.4.1. Lipids Characterization

Fatty acids were analyzed by gas chromatography (GC/FID), based on the preparation of their methyl esters (by cold methylation of the sample dissolved in hexane and mixed with 2 N potassium hydroxide in methanol) and their subsequent separation.

Dietary lipids, composed of fatty acids, can exert either beneficial or detrimental effects on human health, influencing the onset or prevention of various diseases. Given that these fatty acids naturally exist as a mix of saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA), it becomes essential to assess their overall nutritional and therapeutic implications. In this study, we analyzed the fatty acid profile of octopus samples collected across four seasonal periods at each sampling site throughout a one-year span. From these data, we calculated several nutritional indices and reported the results as the mean \pm SEM.

2.4.2. Atherogenicity Index (AI)

The AI reflects the balance between pro-atherogenic saturated fatty acids—excluding stearic acid (C18:0), which is generally considered neutral due to its conversion to oleic acid in humans—and unsaturated fatty acids. It is computed using the formula [11]:

$$AI = [C12:0 + (4 \times C14:0) + C16:0] / (\sum UFA)$$

2.4.3. Thrombogenicity Index (TI)

The TI quantifies the potential of fatty acids to promote thrombus formation. This index differentiates between pro-thrombogenic fatty acids (C12:0, C14:0, C16:0) and those with anti-thrombogenic properties, such as MUFAs and ω -3 and ω -6 PUFAs. The equation is as follows [30]:

$$TI = [(C14:0 + C16:0 + C18:0) / (0.5 \times MUFA) + (0.5 \times \sum \omega\text{-6 PUFA}) + (3 \times \sum \omega\text{-3 PUFA}) + (\sum \omega\text{-3 PUFA} / \sum \omega\text{-6 PUFA})]$$

2.4.4. Hypocholesterolemic/Hypercholesterolemic (hH) Fatty Acids Ratio

This ratio evaluates the impact of dietary fats on plasma cholesterol levels, particularly the balance between fatty acids that lower (C18:1n-9, PUFA) and those that raise (C12:0, C14:0, C16:0) LDL cholesterol [30]:

$$hH \text{ ratio} = (C18:1 + \sum PUFA) / (C12:0 + C14:0 + C16:0)$$

2.4.5. Ratio Omega 6/Omega 3 (ω -6/ ω -3)

This measure assesses the nutritional quality of food in terms of essential fatty acid balance. It is calculated by [30]:

$$\omega\text{-6}/\omega\text{-3} = (C18:2n\text{-6} + C20:2n\text{-6} + C20:3n\text{-6} + C20:4n\text{-6}) / (C18:3n\text{-3} + C20:3n\text{-3} + C20:5n\text{-3} + C22:5n\text{-3} + C22:6n\text{-3})$$

2.4.6. PUFA/SFA and UFA/SFA Ratios

These two indices serve as direct indicators of cardiovascular health implications by comparing unsaturated to saturated fatty acids [30]:

$$PUFA/SFA = (\sum PUFA) / (\sum SFA)$$

$$UFA/SFA = (\sum UFA) / (\sum SFA)$$

2.4.7. EPA and DHA

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are long-chain ω -3 PUFAs integral to numerous physiological functions. The combined proportion of EPA and DHA is often used as a biomarker for cardiovascular and neurological health benefits [30].

Linoleic (LA)/Alpha-linolenic acid (ALA) ratio

This index is particularly relevant in estimating long-chain PUFA synthesis potential and has been employed in evaluating the nutritional adequacy of infant formulas [30]:

$$\text{LA/ALA} = (\text{C18:2n-6})/(\text{C18:3n-3})$$

2.5. Statistical Analyses

Sample data were treated separately according to the origin of the samples, leeward and windward, and periods of the year.

Results are expressed as the average \pm SEM. Statistical significance was assessed using Student's *t*-test ($p < 0.05$) to find out if there are significant differences between the octopus captured from leeward or windward.

3. Results

3.1. Proximal Composition and Amino Acids Analyses

Table 1 shows the chemical composition of octopus from the two origins. The amount of protein is between 16.2 and 17.7 g/100, leeward vs. windward, respectively. Moisture was found to be very similar for both batches: 79 vs. 81 g/100 g (windward vs. leeward). The concentration of sodium, as an essential element, was 0.35–0.51 g/100 g, and the amount of salt was 0.88–1.19 g/100 g (windward vs. leeward). Energy value was estimated to be 75–65 Kcal/100 g (windward vs. leeward), indicating that this species is low in calories. The values for total fat and carbohydrates have also been included. When presented in accordance with their usual expression in a nutritional analysis (g/100 g), a result of less than 1 and 2, respectively, was observed, which corresponds to the method's detection limit. Significant differences in the content of sodium, salt, and energy value regarding the origin of the octopus were found. In contrast, the rest of the parameters were not statistically significant.

Table 1. Nutritional composition of windward and leeward common octopus (*Octopus vulgaris*).

Common Octopus Nutritional Parameters (g/100 g)	Windward		Leeward	
	Average	SEM	Average	SEM
Protein	17.75	0.55	16.23	1.08
Na	0.35	0.01	0.51	0.02
Salt	0.875	0.01	1.19	0.07
Moisture	79.5	0.65	81.25	0.85
Ash	1.88	0.09	2.04	0.08
Carbohydrates	<2	-	<2	-
Total fats	<1	-	<1	-
Energetic value (Kcal/100 g)	75.5	2.60	64.73	2.47

3.2. Characterization of Nutritional Quality

We evaluated the amino acid composition and the content (g/100 g) in each batch of octopus, as shown in Table 2. Glutamic acid (2.25–2.33 g/100 g, leeward vs. windward) was found to be the major component within muscle proteins, followed by ornithine and

taurine, aspartic, arginine, leucine, and lysine. Tryptophan was not analyzed. No significant statistical differences were found based on the octopus origin.

Table 2. Composition and amount of amino acids (g/100 g) analyzed in windward and leeward common octopus (*Octopus vulgaris*). Average \pm SEM ($n = 3$).

<i>Octopus vulgaris</i> Amino acids (g/100 g)	Windward		Leeward	
	Average	SEM	Average	SEM
Cysteine	0.025	0	0.032	
Methionine	0.28	0.09	0.24	0.03
Alanine	0.45	0.16	0.75	0.18
Arginine	1.08	0.4	1.7	0.16
Aspartic acid	0.99	0.38	1.6	0.32
Glutamic acid	2.33	0.34	2.25	0.31
Glycine	1.07	0.14	0.94	0.88
Histidine	0.5	0.06	0.47	0.01
Hydroxyproline	0.26	0.06	0.15	0.03
Isoleucine	0.78	0.11	0.77	0.09
Leucine	1.28	0.22	1.25	0.2
Lysine	1.23	0.22	1.19	0.19
Ornithine/Taurine	1.5	0.2	1.39	0.06
Phenylalanine	0.58	0.04	0.53	0.02
Proline	0.76	0.12	0.70	0.07
Serine	0.79	0.15	0.71	0.10
Threonine	0.97	0.17	0.95	0.11
Tyrosine	0.45	0.04	0.43	0.03
Valine	0.75	0.07	0.75	0.06

Figure 1 illustrates the amino acid composition of octopus essential amino acids (EAA), those that our organism cannot synthesize, and the non-essential amino acids (NEAA) that humans can produce. In both cases, the percentage of essential amino acids is high, near 40%.

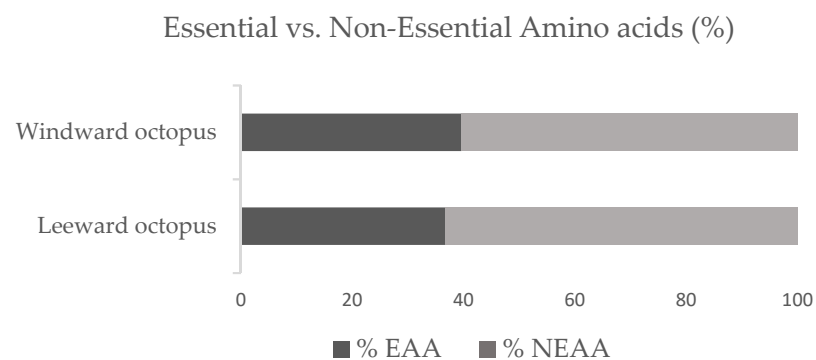


Figure 1. Percentage of essential (EAA) vs. non-essential (NEEA) amino acids in octopus, both windward and leeward. Average of three samples for each origin.

Other nutritional quality indicators, such as FR and PER, were estimated. The values obtained were very high in both batches of octopus, as shown in Table 3.

Table 3. Estimation of FR and PERest in windward and leeward octopus.

	Windward Octopus	Leeward Octopus
Fischer ratio	2.59	2.89
PERest	5.06	3.68

To provide more nutrition information, the octopus amino acid score was estimated by comparing it with the recommended amino acid score.

Results show that octopus contain all essential amino acids (EAAs) required to meet the recommended amino acid concentrations per unit protein for children older than three years, adolescents, and adults (aa score > 100%), Figure 2A,B. However, results show that it seems to be deficient in methionine and cysteine (aa score 75%) (Figure 2B). Nevertheless, it is known that cys is highly unstable; it forms oxidized compounds or is lost in acid hydrolysis, so with this method, the concentration tends to be underestimated. Work is being done to optimize the method for a more accurate estimation.

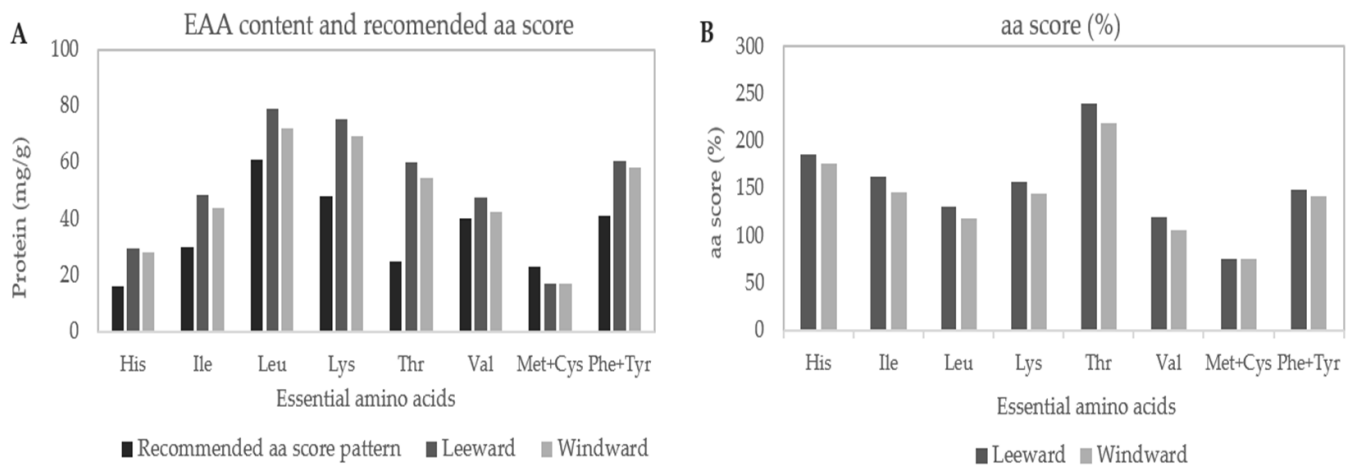


Figure 2. (A,B) Essential amino acid content of octopus and recommended amino acid scoring pattern for children > 3, adolescent and adult.

3.3. Fatty Acid Composition

Lipids play positive or negative roles in human metabolism, health, and disease. The average amount of each fatty acid was used to calculate the sum of the SFAs, MUFAs, PUFAs, EPA + DHA, ω -3, ω -6, and trans-SFAs. The lipid content of octopus is very low. As shown in Table 4, the obtained value for saturated fatty acids is below 0.1 g/100, which is a very healthy result. Trans-fatty acids were not detected, as expected. The sum of EPA and DHA is around 50–65 mg/100 g.

Table 4. Fatty acid composition of windward and leeward common octopus (*Octopus vulgaris*).

<i>Octopus vulgaris</i> Fatty acids (g/100 g)	Windward		Leeward	
	Average	SEM	Average	SEM
Saturated fatty acids	<0.1	-	<0.1	-
Monounsaturated fatty acids	0.0325	0.002	0.03	0.007
Polyunsaturated fatty acids	0.075	0.017	0.085	0.011
EPA + DHA	0.05	0.015	0.065	0.009
Omega-3	0.065	0.017	0.0775	0.011
Omega-6	0.01	0	0.01	0.0
Trans polyunsaturated fatty acids	<0.01	-	<0.01	-

3.4. Qualitative and Nutritional Indexes of Lipids

Lipids are present in foods as mixtures of SFA, MUFA, and PUFA, having different roles in the human body. Then, to evaluate the nutritional and medicinal values of octopus as food, it was appropriate to estimate some qualitative and nutritional indexes that give information about the effect on human health:

3.5. AI and TI

The Atherogenicity Index (AI) serves to quantify the potential of dietary fatty acids to promote atherogenesis by comparing specific saturated fatty acids (SFAs) with unsaturated fatty acids (UFAs). Stearic acid (C18:0) is excluded from this index due to its metabolic conversion into oleic acid in the human body, which renders it non-atherogenic. In contrast, lauric (C12:0), myristic (C14:0), and palmitic (C16:0) are recognized for enhancing lipid accumulation in vascular and immune cells, fostering plaque formation, and diminishing levels of phospholipids and esterified fatty acids. Compared to broader indices like the PUFA/SFA ratio, AI provides a more targeted and refined measure of a food's atherogenic potential.

The Thrombogenicity Index (TI) evaluates the tendency of fatty acids to contribute to thrombus (blood clot) formation. It classifies fatty acids based on their derived eicosanoid activity into pro-thrombogenic components—primarily C12:0, C14:0, and C16:0—and anti-thrombogenic agents such as monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), particularly from the n-3 (omega-3) and n-6 (omega-6) series. However, emerging research suggests that certain n-6 PUFAs may also play a role in promoting thrombogenesis, calling into question their exclusively protective classification.

Figure 3 shows that values obtained for AI and TI in octopus are very low, indicating positive effects on health. In our hands, AI-obtained value is lower than 0.5 and TI is lower than 0.01. There were no significant differences in any case.

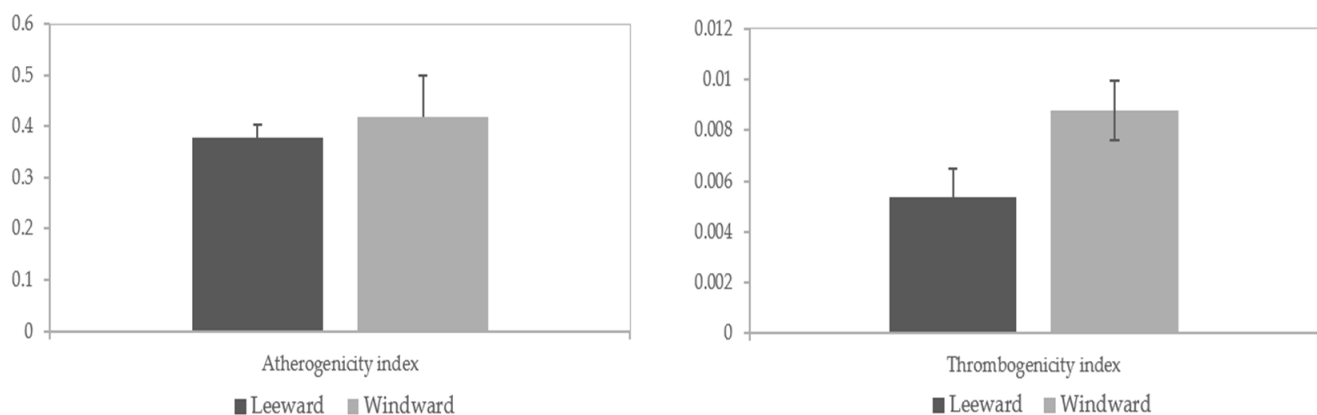


Figure 3. Representation of atherogenicity and thrombogenicity indexes estimated in leeward and windward octopus, captured in different seasons. Average \pm SEM ($n = 4$).

3.6. hH and ω -6/ ω -3

The hH focuses on the ratios between dietary fatty acids and plasma low-density lipoproteins that relate hypocholesterolemic and hypercholesterolemic fatty acids. It is a direct index; the higher this index, the greater the effects on health.

The ω -6/ ω -3 ratio is an indicator of the biomedical importance of marine fish, and the correct balance between both figures is recommended.

Figure 4 shows that values obtained for the h/H ratio in octopus are high, close to 3, consistent with the bibliography and indicating good effects on health. In contrast, the ω -6/ ω -3 ratio is extremely low (0.1–0.2), and even lower regarding the reference values. The value obtained in the ratio ω -6/ ω -3 is quite different between the leeward and windward octopus, being in the former half of that obtained in the windward octopus. However, it should be noted that these differences are not statistically significant.

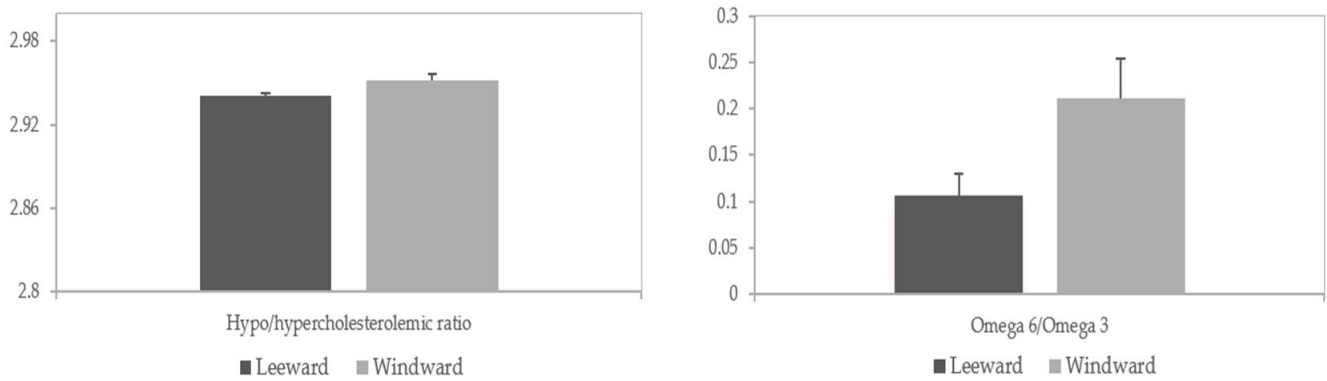


Figure 4. Hypocholesterolemic/hypercholesterolemic and omega 6/omega 3 ratios obtained in leeward and windward octopus, captured in different seasons. Average \pm SEM ($n = 4$).

3.7. PUFA/SFA and UFA/SFA Ratios

The PUFA/SFA ratio reflects the balance between polyunsaturated and saturated fatty acids in each food source. Polyunsaturated fatty acids (PUFAs) are generally associated with cholesterol-lowering effects, particularly in reducing levels of low-density lipoprotein (LDL) and overall serum cholesterol. In contrast, saturated fatty acids (SFAs) are known to elevate serum cholesterol, thereby increasing cardiovascular risk. A higher PUFA/SFA ratio is therefore considered favorable for cardiovascular health. Similarly, the UFA/SFA ratio, which encompasses both monounsaturated and polyunsaturated fatty acids relative to saturated fatty acids, serves as another key nutritional index. This ratio has been linked to the risk profile for coronary artery disease, with higher values suggesting a more cardioprotective fatty acid composition.

The values obtained for the PUFA/SFA ratio as well as the UFA/SFA are high and higher than the recommended in the bibliography, as shown in Figure 5. So, these results indicate that these products have positive effects to prevent cardiovascular disease. No significant differences were observed between leeward and windward octopus.

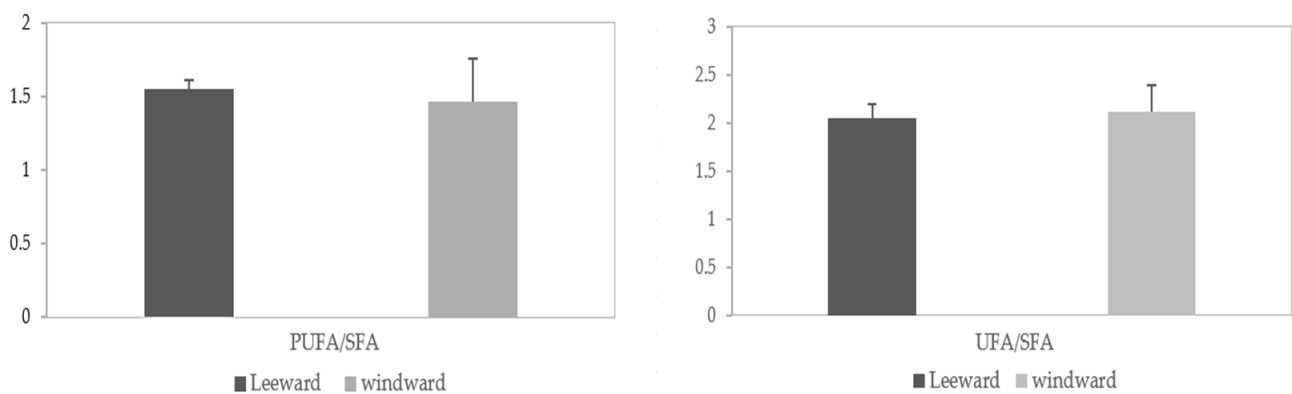


Figure 5. PUFA/UFA ratio and UFA/SFA ratio obtained in leeward and windward octopus, captured in different seasons. Average \pm SEM ($n = 4$).

3.8. EPA + DHA (%) and LA/ALA Ratio

The sum of EPA and DHA, as a percentage of fatty acids, is a direct index that correlates with human health. The dietary ratio of LA/ALA is a controversial subject since the role of these fatty acids on inflammation and obesity.

We observed that in both octopus, the sum of EPA and DHA is higher than 30%, which means a protective effect against coronary disease. However, the LA/ALA ratio is high, according to the high values obtained for LA compared to ALA, which are much

lower (Figure 6). The LA average values obtained in the leeward octopus correspond to 6.75 mg/100 g, while those of ALA are almost 10 times lower, 0.875 mg/100 g. In relation to the windward octopus, even higher values were reached for LA, 10 mg/100 g, and again much lower values for ALA, 0.575 mg/100 g. In relation to this result, we cannot state conclusive results since the role of LA is controversial due to it being converted to ARA (pro-inflammatory), but at a very low rate [31].

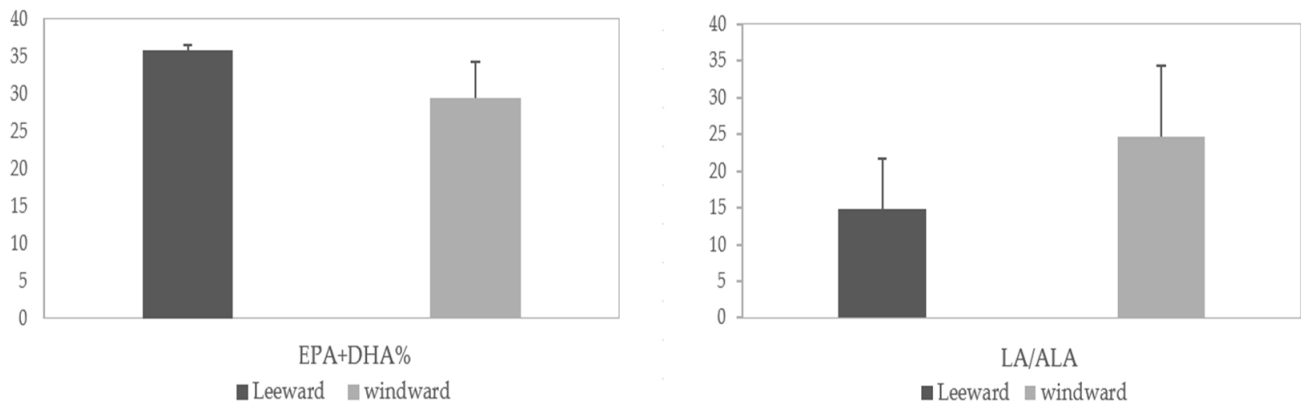


Figure 6. Sum of EPA and DHA (%) and LA/ALA ratio obtained in leeward and windward octopus, captured in different seasons. Average \pm SEM ($n = 4$).

No seasonal differences in indexes of lipids were observed in downward octopus regarding the seasonality. However, in windward octopus, we detected significant differences between samples from warm seasons with respect to the colder in four lipid quality indexes. Better results were obtained in AI, TI, h/H, and ω -6/ ω -3 fatty acids in the winter samples compared to the summer ones.

3.9. Minerals and Vitamins Content

Healthy and nutritional properties related to octopus depend on the presence of certain minerals and vitamins as well. Then, micronutrients, susceptible to being present in these products, were analyzed in both windward and leeward batches of octopus; results are presented as average \pm SEM of 2 or 3 samples, as shown in Table 5. No significant differences were obtained between the two types of samples.

Table 6 compiles the results obtained for both sets of octopus samples, considering the origin. In the first column on the left, the type of mineral or vitamin and the units (according to EU Regulation 1169/2011) were included. Following the information established in the legislation, the second column presents the nutrient reference value (NRV) for each vitamin or mineral; the third column, the value calculated to be able to label the food as “rich in”; and the fourth, the estimated value to label the food as “high content in”. The fifth and sixth columns present the average data obtained for the octopus, windward and leeward, respectively. In this context, we can highlight that both octopuses are rich in Mg and P and have a high content of vitamin B12 and Se. Moreover, octopus from windward is rich in biotin and has a high content of Cu and octopus from leeward is rich in Cu. However, values are very similar for octopus from both origins, so these measures should be taken with caution since they could be modified if more samples were analyzed.

Table 5. Results of vitamins and minerals analyzed in leeward and downward common octopus (*Octopus vulgaris*). Average \pm SEM ($n = 2/3$ samples).

<i>Octopus vulgaris</i>	Windward		Leeward	
	Minerals and Vitamins	Average	SEM	Average
Se (mg/kg)	0.26	0.01	0.26	0.02
K (mg/100 g)	262.7	17.1	277.0	17.2
Zn (mg/kg)	13.3	0.38	14.7	0.35
P (mg/100 g)	157.7	12.99	164.0	11.9
Mg (mg/kg)	673.3	60.1	590.7	6.36
Ca (mg/100 g)	18.5	2.5	18.0	1.0
I (mg/kg)	0.08	0.02	0.1	0.001
Cu (mg/kg)	2.17	0.35	3.73	0.55
Thiamin-B1 (mg)	<0.015	0.0	<0.015	0.0
Riboflavin-B2 (mg)	0.03	0.0	0.03	0.0
Niacin-B3 (mg)	1.56	0.17	1.74	0.05
Pantothenic acid-B5 (mg)	0.31	0.0	0.39	0.0
Piridoxin-B6 (mg)	0.06	0.0	0.07	0.0
Biotin-B8 (μ g)	6.63	3.08	8.15	0.61
Folic acid-B9 (μ g)	<5	0.0	<5	0.0
Cyanocobalamin-B12 (μ g)	1.05	0.3	1.20	0.26
Vitamin E (mg)	1.05	0.35	1.50	0.40

Table 6. Results of minerals or vitamins obtained in windward and leeward common octopus (*Octopus vulgaris*); the nutrient reference value (NRV); the value calculated to be able to label as “rich in” and as “high content in”.

Vitamins and Minerals	Nutrient Reference Value (NRV)	Significant Amount	Significant Amount	Octopus	Octopus
		15%/100 g/mL	30%	Windward	Leeward
		Rich In	High Content In	Average	Average
Thiamin-B1 (mg)	1.1	0.165	0.33	<0.015	<0.015
Riboflavin-B2 (mg)	1.4	0.21	0.42	0.03	0.03
Niacin-B3 (mg)	16	2.4	4.8	1.74	1.56
Piridoxin-B6 (mg)	1.4	0.21	0.42	0.07	0.06
Biotin-B8 (μ g)	50	7.5	15	8.15	6.63
Folic acid-B9 (μ g)	200	30	60	<5	<5
Cyanocobalamin-B12 (μ g)	2.5	0.375	0.75	1.20	1.05
Pantothenic acid-B5 (mg)	6	0.9	1.8	0.39	0.31
Vitamin E (mg)	12	1.8	3.6	1.5	1.05
Magnesium (mg)	375	56.25	112.5	59	67
Zinc (mg)	10	1.5	3	1.47	1.33
Copper (mg)	1	0.15	0.3	0.37	0.22
Selenium (μ g)	55	8.25	16.5	26	26
Ca (mg)	800	120	240	18	18.5
Iodine (microg)	150	22.5	45	9.5	8.15
Potassium (mg)	2000	300	600	277	263
Phosphorus (mg)	700	105	210	164	158

4. Discussion

4.1. Nutritional Profile

Octopus is a good source of essential nutrients with a genuine sensorial profile. In this study, we focused on common octopus (*Octopus vulgaris*) captured by the Portuguese small-scale fishing fleet of the Algarve.

The obtained proximal composition of octopus agrees with other authors [32,33]. This cephalopod has a high protein content (16–17 g/100 g) and an excellent profile of amino acids, with glutamic acid (>2 g/100 g) being the most abundant. When considering the origin of the octopus, windward vs. leeward, respectively, significant differences in the content of sodium (0.35–0.5 g/100 g), salt (0.9–1.2 g/100 g), and energetic value (75.5 to

64.7 Kcal/100 g) were found. This result is probably due to the different habitats in which the octopuses live, two geographically distinct areas. Indeed, the leeward region of the Algarve is predominantly composed of sandy substrates, and the windward region of the Algarve is dominated by erosional landforms [34]. The rest of the parameters evaluated were not statistically significant.

The nutritional value regarding the quality of structurally different proteins depends in part on amino acid composition and ratios of essential amino acids. The greater the ratio of indispensable amino acids, the greater the biological value or quality [31]. In this study, a characterization of nutritional quality, focusing on different indicators published in the literature, was performed. Either in leeward or in windward octopus, the percentage of essential amino acids, those that our organism cannot synthesize and need to be incorporated through diet, is higher than the recommended values of ideal protein intake for adults (11%) and for children (26%) and very close to the ones recommended for infants (39%) [35]. In other seafood products, the results are quite similar; in raw *Scomber scombus* and *Clupea harengus*, the percentage of essential amino acids is 46% and 44%, respectively [36]. This result, together with the fact that amino acids, generally regarded as essential for humans, are present in octopus (except for tryptophan, not analyzed), indicates that this product has important nutritional value since it is a good source of quality proteins and amino acids.

Another nutritional quality indicator is the FR, important for assessing liver metabolism, hepatic functional reserve, and the severity of liver dysfunction [9,10]. The plasma levels of branched-chain amino acids decrease when liver dysfunction progresses, while the aromatic amino acids increase, decreasing Fischer's ratio. Additionally, some studies have shown that a diet rich in branched-chain amino acids is associated with a lower prevalence of obesity and a lower risk of diabetes [37]. Originally, FR was observed in some plants or animal proteins, achieving for Antarctic krill or pearl oyster, values of 2.22 [38] or 3.05 [31], respectively. FR values higher than 3.0 contribute to significant improvement in clinical findings, helping normalization of plasma amino acids and the maintenance of appropriate protein intake [30,39], and it has been shown that proteins with high FR can be a source of bioactive peptides with significant physiological activities [40]. In fact, some studies have been especially developed in pearl oyster *Pinctada martensii* and other seafood products to obtain high Fischer ratio oligopeptides via proteolysis for the treatment of patients with hepatic disease [40]. In the raw octopus meat FR, the obtained values were close to 3 (>2.5), which ensures a protein source of high biological value.

According to [41], a PER below 1.5 is described as a protein of low quality; between 1.5 and 2.0, intermediate quality; and above 2.0, good or high quality. PER estimation of octopus indicated high levels of PER (>3.7) and higher values than casein, assuming a standard PER of 2.5 for this protein. So, octopus can be considered to have a protein of high quality with higher value than casein [31,36].

Regarding these nutritional parameters, some differences were observed between both origins of octopus; however, they were not statistically significant.

4.2. Indexes of Lipids

Marine resources are a good source of PUFAs, although these can vary depending on the diet, season, species characteristics, etc. The octopus fatty acid composition shows that PUFA are the most abundant in octopus (75–85 mg/100 g, windward vs. leeward), followed by MUFA (30 g/100 g) and SFA (with a level lower than 0.1 g/100 g). Concerning total PUFA, ω -3 fatty acids are the most common (65–77 mg/100 g, windward vs. leeward), and ω -6 is present in low amounts (10 mg/100 g). The lipids that contributed most to total PUFA were EPA and DHA (50–65 mg/100 g as the sum of both, windward vs. leeward). It is known that these fatty acids cause important health benefits to humans because they

decrease factors associated with cardiovascular disease, hypertension, and inflammation, among others. In comparison with publications referring to octopus, minor differences are observed in the results of types of fatty acids, probably due to the species, geographical location, and season of capture [32,39].

Considering that the determination of the fatty acid profile, especially if expressed as a percentage, is not sufficient to explain the nutritional properties of a food resource, we have calculated some lipid nutritional and quality indexing, taken from the bibliography, that more effectively explores the octopus's nutritional characteristics and significance regarding health effects [30].

The atherogenicity (IA) and thrombogenicity (IT) indexes indicate the potential to stimulate the aggregation of platelets. Thus, the smaller the IA and IT levels, the higher the protective effect for coronary artery disease. AI has been used extensively to evaluate algae, crops, meat, fish, and dairy products. This value ranges from 0.21 to 1.41 for fish and 0.29–0.37 for shellfish. The ranges of TI values for fish and shellfish are 0.14–0.87 and 0.09–0.17, respectively [42]. In our case, the values obtained for AI and TI were very low, consistent with the bibliography and indicating very good positive effects on health [43]. These indexes are within the range of expected values; the AI obtained value is lower than 0.5, and TI is lower than 0.01; therefore, from this point of view, the consumption of octopus is valued for human health due to its cardioprotective effects.

The index h/H is related to cholesterol metabolism, so nutritionally, lower h/H values are considered to have greater effects on health. For fish, the values range from 1.54 to 4.83, and for shellfish, from 0.21 to 4.75 [42]. In octopus, we obtained values lower than 3, consistent with the bibliography [39] and indicating a protective role on human health by equilibrating the effects derived from cholesterol ingestion.

The ω -3/ ω -6 ratio is an indicator of the biomedical importance of marine fish, and the correct balance between both figures is recommended. A reduced omega-6 to omega-3 fatty acid ratio is considered more beneficial for health, as it is linked to a decreased incidence of numerous chronic conditions that are commonly observed in both industrialized and developing regions. Large amounts of ω -6 in the human diet have been reported to cause health disorders, while ω -3 appears to alter the adverse effects of ω -6. Adjusting the ω -6/ ω -3 ratio in the diet is essential to prevent chronic inflammation and cardiovascular diseases by lowering plasma lipids. According to the authorities, a ratio of ω -6/ ω -3 fatty acids within the range of 0.2–1.15 would contribute to a healthy human diet. If the ratio of ω -6/ ω -3 is less than 4, then the diet has a desirable quantity of ω -3 and ω -6 fatty acids and reduces cardiovascular diseases [44,45].

In our study, the ω -6/ ω -3 ratio is extremely low (0.1–0.2), and even lower than the reference values, which means that eating octopus can help decrease the risk of cardiovascular disease. For instance, in raw Nile tilapia, this ratio was 4.76, almost within the standard, but in fried fish, this value increased considerably to 19.98%. So, the culinary preparation of seafood should be taken into account when the effects on health are considered. The value obtained in the ratio ω -6/ ω -3 is quite different between the leeward and windward octopus, being in the former half of that obtained in the windward octopus. However, it should be noted that these values are very low, and differences are not statistically significant.

It is clear that both total fat content and unsaturated-to-saturated FA ratio of the diet are highly important. The polyunsaturated fatty acids are characterized by the presence of multiple double bonds. In contrast to saturated fats, which have no double bonds and form solid structures, unsaturated fatty acids are more fluid, and their bonds keep molecules flexible and prevent them from packing closely together. This provides appropriate membrane permeability and is essential for the operation of cell membranes, including the

signaling pathways processes. This characteristic is key for the recommendation of PUFAs in preventive diets to improve human health [46].

PUFA/SFA is a direct index based on the fact that all PUFAs are able to reduce low-density lipoprotein cholesterol and serum cholesterol, while all SFAs can contribute to increasing serum cholesterol. In addition, the UFA/SFA ratio of the diet is highly important to reduce the risk of coronary heart disease. Indeed, the ratio of UFA/SFA and PUFA/SFA greater than 0.45 is recommended in human diets for cardiovascular disease (CVD) and chronic disease prevention [44]. In contrast, a diet with a ratio of UFA/SFA and PUFA/SFA below 0.45 is considered unsuitable due to its potential to induce an increase in cholesterol in the blood. In this study, PUFA/SFA and UFA/SFA are 1.6 and 2, respectively, without differences regarding the origin, indicating that consumption of this cephalopod is beneficial for human health.

It is an accepted industry standard that the oil intended for human consumption should contain 30% of EPA plus DHA, where an 18/12 ratio is the most preferred and valuable profile [47]. In this study, the sum of EPA and DHA is higher than 30%, which means it has a protective effect and is beneficial for heart, cardiovascular, and brain function.

Taking into consideration the fact that the omega-3 fatty acids, EPA, DHA, and ALA are three forms of lipids essential for health that must be obtained from the diet, and their modulatory effects on inflammation, neuroprotective properties, and role in mitigating cardiovascular risk factors, it is fair to assume that including octopus in our diets has important benefits for human health. We also evaluated possible content differences depending on the season of the year (autumn–winter vs. the spring–summer seasons) in which the tested octopuses were caught. No differences were observed in the leeward octopus regarding seasonality. However, in windward octopus, we detected significant differences between samples from warm seasons concerning to the colder in four lipid quality indexes. In particular, better results were obtained in AI, TI, h/H, and ω -6/ ω -3 fatty acids in the winter samples compared to the summer ones. Octopus fatty acid composition is affected by diet and depends on prey, so feeding habits are connected with the geographical region and water temperature; in cold water, octopuses store more fat [40].

As aforementioned, in the windward region of the Algarve, rocky outcrops are common, with a characteristic faunistic composition of, e.g., shrimps and crabs. Conversely, in the leeward region, fishing grounds are typically composed of sandy areas where, e.g., bivalves, gastropods, and hermit crabs abound and, therefore, are more available as food sources [48–51]. Further, the western coast of the Algarve is more exposed to the influence of the Atlantic Ocean, which results in generally cooler water. Conversely, the eastern coast of the Algarve is more affected by Mediterranean currents and higher inland temperatures, which can lead to warmer coastal waters [15–17].

4.3. Microelements

The main objective of Regulation (EU) 1169/2011 is to ensure and guarantee that consumers are appropriately informed as regards the food they consume in order to achieve a high level of health protection [42]. According to this regulation, a product can be “rich in (...)”, if it contains more than 15% of the nutrient reference value (NRV) or has a “high content in (...)”, if it contains more than 30% of an NRV in a particular nutrient. In this study, we can assess that octopuses from both origins are rich in Mg and P and have a high content of vitamin B12 and Se. Despite all values being very similar for octopus from both origins, slight differences can be seen. The samples from windward are rich in biotin and have high content of Cu, and octopus from leeward is rich in Cu.

In this species, the high content of certain micronutrients, vitamins, and minerals also stands out, highlighting vitamins B8 and B12, magnesium, copper, selenium, and

phosphorus. Several studies have shown that the combination of B-group vitamins, omega-3 fatty acids, and minerals supports cognitive health, memory, and may reduce the risk of neurodegenerative diseases [52]. In addition, the content of Se, a powerful antioxidant that protects cells from damage, supports thyroid function [52].

In our study, the analyzed octopuses do not present any risk to human health from the sanitary point of view since all the contaminants evaluated are either absent or in an extremely low concentration and very well below the legislated limit. All not regulated parameters with non-established limits were also found in concentrations below the ones published in the bibliography [53]. These findings also reflect the good environmental condition of the Algarve coastal area.

Regarding consumer acceptance, from an organoleptic point of view, both octopuses seem to offer excellent quality, with a particularly good assessment of their sensory attributes by the expert panel of tasters (Supplementary Materials).

This was the first study assessing the nutritional profile of the octopus captured in Algarve small-scale fishing, a vital component of the Portuguese economy and gastronomy. The comprehensive analysis reveals that Algarve-caught octopus represents an exceptional seafood choice, characterized by its remarkable nutritional density and sustainability credentials. The species presents notable nutritional properties, characterized by elevated protein content, with high-quality, diverse mineral profiles, and important vitamins. Also, octopus contain a beneficial fatty acid composition, collectively contributing to enhanced cardiovascular health and overall physiological well-being.

Our findings validate the premium market position of Algarve octopus, evidenced by its substantial first-sale average value of 7.76 EUR/kg in 2023 [7], while underscoring its crucial role in maintaining the economic vitality of Portugal's seafood sector. The integration of these nutritional findings with economic metrics reinforces the importance of preserving traditional small-scale fishing practices in the Algarve region, highlighting their dual contribution to both public health and regional economic sustainability.

Supplementary Materials: The supporting information regarding Organoleptic analysis can be downloaded at: <https://www.mdpi.com/article/10.3390/app15158235/s1>. Figure S1: Sensorial attributes in frozen (general aspect/colour and odour) and thawed (external colour, odour and texture) windward octopus. Average obtained in 4 samples captured in different seasons and evaluated by testers. Figure S2: Sensorial attributes in boiled windward octopus. Average obtained in 4 samples evaluated by testers and captured in different seasons. Figure S3: Sensorial attributes in frozen (general aspect/colour and odour) and thawed (external colour, odor and texture) leeward octopus. Average obtained in 4 samples captured in different seasons and evaluated by testers. Figure S4: Sensorial attributes in boiled leeward octopus. Average obtained in 4 samples captured in different seasons and evaluated by testers.

Author Contributions: A.G.C. conceptualization and design of the work, interpretation, and discussion of results; partial drafting of the article and general revision; M.R. sampling design and sample collection; partial drafting of the paper, review, editing, and submission; C.C. methodology and direction of laboratory analyses; discussion of results and general review; D.B.d.S. methodology and partial supervision of laboratory analyses; partial drafting, discussion of results, and general review; J.P. sampling design, samples search and collection; partial writing, discussion and general review. All authors have read and agreed to the published version of the manuscript.

Funding: This study has received funding under the Horizon Europe Research and Innovation programme, Grant agreement No. 101060564—Sea2See project. This study also received Portuguese national funds from FCT—Foundation for Science and Technology through projects UIDB/04326/2020 (DOI:10.54499/UIDB/04326/2020), UIDP/04326/2020 (DOI:10.54499/UIDP/04326/2020) and LA/P/0101/2020 (DOI:10.54499/LA/P/0101/2020). MR also acknowledges the project reference 2022.03096.CEECIND (<https://doi.org/10.54499/2022.03096.CEECIND/CP1729/CT0007>).

Data Availability Statement: The original contributions presented in this study are included in the article and Supplementary Materials. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Pita, C.; Roumbedakis, K.; Fonseca, T.; Matos, F.L.; Pereira, J.; Villasante, S.; Pita, P.; Bellido, J.M.; Gonzalez, A.F.; García-Tasende, M. Fisheries for common octopus in Europe: Socioeconomic importance and management. *Fish. Res.* **2021**, *235*, 105820. [CrossRef]
2. Rangel, M.; Pita, C.; Oliveira, M.M.; Guimarães, M.H.; Ballesteros, M.; Rainha, R.; Sonderblohm, C.; Monteiro, P.; Oliveira, F.; Gonçalves, J.M.S.; et al. Do fisher associations really represent their members' needs and opinions? The case study of the octopus fishery in the Algarve (south Portugal). *Mar. Policy* **2019**, *101*, 276–284. [CrossRef]
3. Pita, C.; Pereira, J.; Lourenço, S.; Sonderblohm, C.; Pierce, G.J. The traditional small scale octopus fishery in Portugal: Framing its governability. In *Interactive Governance for Small-Scale Fisheries*; Jentoft, S., Chuenpagdee, R., Eds.; Springer: Cham, Switzerland, 2015.
4. Sonderblohm, C.P.; Guimarães, M.H.; Pita, C.; Rangel, M.O.; Pereira, J.; Gonçalves, J.M.S.; Erzini, K. Participatory assessment of management measures for *Octopus vulgaris* pot and trap fishery from southern Portugal. *Mar. Policy* **2017**, *75*, 133–142. [CrossRef]
5. Sonderblohm, C. Fishery Dynamics and Participatory Management of the Common Octopus (*Octopus vulgaris*) Pot and Trap Fishery in Southern Portugal. Ph.D. Thesis, University of Algarve, Faro, Portugal, 2015.
6. Moreno, A.; Lourenço, S.; Pereira, J.; Gaspar, M.B.; Cabral, H.N.; Pierce, G.J.; Santos, A.M.P. Essential habitats for pre-recruit *Octopus vulgaris* along the Portuguese coast. *Fish. Res.* **2014**, *152*, 74–85. [CrossRef]
7. INE. Estatística de Pesca: 2023. Available online: <https://www.ine.pt> (accessed on 10 April 2025).
8. Rosa, R.; Roura, Á.; Amor, M.; Gleadall, I.G.; Guerra, Á.; González, Á.F.; Lopes, V.M.; Pereira, J.; Pierce, G.J.; Sampaio, E. Octopus vulgaris, the common octopus. In *Octopus Biology and Ecology*; Elsevier: Amsterdam, The Netherlands, 2024; pp. 187–216.
9. Almeida, C.; Loubet, P.; Laso, J.; Nunes, M.L.; Marques, A. Environmental assessment of common octopus (*Octopus vulgaris*) from a small-scale fishery in Algarve (Portugal). *Int. J. Life Cycle Assess.* **2022**, *27*, 849–867. [CrossRef]
10. Lourenco, S.; Moreno, A.; Narciso, L.; González, Á.F.; Pereira, J. Seasonal trends of the reproductive cycle of *Octopus vulgaris* in two environmentally distinct coastal areas. *Fish. Res.* **2012**, *127*, 116–124. [CrossRef]
11. Hernández-García, V.; Hernández-López, J.; Castro-Hdez, J. On the reproduction of *Octopus vulgaris* off the coast of the Canary Islands. *Fish. Res.* **2002**, *57*, 197–203. [CrossRef]
12. Zamuz, S.; Bohrer, B.M.; Shariati, M.A.; Rebezov, M.; Kumar, M.; Pateiro, M.; Lorenzo, J.M. Assessing the quality of octopus: From sea to table. *Food Front.* **2023**, *4*, 733–749. [CrossRef]
13. Government of the Netherlands. The European Market Potential for Octopus. 2020. Available online: <https://www.cbi.eu/market-information/fish-seafood/octopus/market-potential> (accessed on 10 May 2025).
14. Sonderblohm, C.; Guimarães, H.; Rainha, R.; Gonçalves, J.M.S.; Pereira, J.; Gaspar, M.; Erzini, K.; Rangel, M. *Livro Verde Sobre a Pesca do Polvo no Algarve*; Centro de Ciências do Mar (CCMAR): Faro, Portugal, 2016.
15. Bettencourt, A.M.B.; Bricker, S.B.; Ferreira, J.G.; Franco, A.; Marques, J.C.; Melo, J.J.; Nobre, A.; Ramos, L.; Reis, C.S.; Salas, F.; et al. *Typology and Reference Conditions for Portuguese Transitional and Coastal Waters*; INAG/IMAR Instituto da Água and Institute of Marine Research: Horta, Portugal, 2004; p. 99.
16. Cunha, M.E. Physical Control of Biological Processes in a Coastal Upwelling System. Ph.D. Thesis, University of Lisboa, Lisboa, Portugal, 2001.
17. Leitão, F.; Maharaj, R.R.; Vieira, V.M.N.C.S.; Teodósio, A.; Cheung, W.W.L. The effect of regional sea surface temperature rise on fisheries along the Portuguese Iberian Atlantic coast. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2018**, *28*, 1351–1359. [CrossRef]
18. ISO/IEC 17025:2017; General Requirements for the Competence of Testing and Calibration Laboratories. International Organization for Standardization: Geneva, Switzerland, 2017.
19. International, A. Standard No. AOAC International Official Method 940.25-1940, Nitrogen (Total) in Seafood. Available online: http://www.aocofficialmethod.org/index.php?main_page=product_info&cPath=1&products_id=1081 (accessed on 10 May 2025).
20. AOAC International. Standard No. AOAC International Official Method AOAC 937.07-1996, Fish and Marine Products. Treatment and Preparation of Test Sample Procedure. Available online: http://www.aocofficialmethod.org/index.php?main_page=product_info&cPath=1&products_id=2483 (accessed on 10 May 2025).
21. ISO 13903:2005; Animal Feeding Stuffs—Determination of Amino Acids Content. International Organization for Standardization: Geneva, Switzerland, 2005.
22. EN 14152:2014; Foodstuffs—Determination of Vitamin B2 by High Performance Liquid Chromatography. European Committee for Standardization: Brussels, Belgium, 2014.

23. EN 15652:2009; Foodstuffs—Determination of Niacin by HPLC. European Committee for Standardization: Brussels, Belgium, 2009.
24. EN 14164:2014; Foodstuffs—Determination of Vitamin B6 by High Performance Chromatography. European Committee for Standardization: Brussels, Belgium, 2014.
25. NMKL 111:1985; Total Folate in Food by LC-ESI-MS/MS. Quantification of 6 Folate Vitamers; Nordic-Baltic Committee on Food Analysis (NMKL): Bergen, Norway, 2020.
26. Campos-Gimnez, E.; Fontannaz, P.; Trisconi, M.-J.; Kilinc, T.; Gimenez, C.; Andrieux, P. Determination of vitamin B12 in food products by liquid chromatography/UV detection with immunoaffinity extraction: Single-laboratory validation. *J. AOAC Int.* **2008**, *91*, 786–793. [[CrossRef](#)]
27. Fischer, J.E.; Rosen, H.M.; Ebeid, A.M.; James, J.H.; Keane, J.M.; Soeters, P.B. The effect of normalization of plasma amino acids on hepatic encephalopathy in man. *Surgery* **1976**, *80*, 77–91.
28. Moraes, K.; Pinto, L.A. Protein quality of dried enzymatic hydrolysate from anchovy produced in a spouted bed of inert particles. *Int. J. Food Sci. Technol.* **2015**, *50*, 819–825. [[CrossRef](#)]
29. Consultation, F.E. Dietary protein quality evaluation in human nutrition. *FAO Food Nutr. Pap.* **2011**, *92*, 1–66.
30. Dal Bosco, A.; Mancinelli, A.C.; Vaudo, C.; Cavallo, M.; Castellini, C.; Mattioli, S. Indexing of fatty acids in poultry meat for its characterization in healthy human nutrition: A comprehensive application of scientific literature and new proposals. *Nutrients* **2022**, *14*, 3110. [[CrossRef](#)] [[PubMed](#)]
31. Zheng, H.; Zhang, C.; Cao, W.; Liu, S.; Ji, H. Preparation and characterisation of the pearl oyster (*Pinctada martensii*) meat protein hydrolysates with a high Fischer ratio. *Int. J. Food Sci. Technol.* **2009**, *44*, 1183–1191. [[CrossRef](#)]
32. FoodData Central. Available online: <https://fdc.nal.usda.gov/> (accessed on 30 April 2025).
33. Rosa, R.; Nunes, L.; Reis, C.S. Seasonal changes in the biochemical composition of *Octopus vulgaris* Cuvier, 1797, from three areas of the Portuguese coast. *Bull. Mar. Sci.* **2002**, *71*, 739–751.
34. DGRM, Plano Plurianual de Dragagens para os Portos de Pesca do Algarve (2024–2025). Available online: https://www.dgrm.pt/documents/20143/48268/Plano+PLURI_DRAG_ALGARVE_2024-2026.pdf (accessed on 30 April 2025).
35. Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation. *Food Nutr. Bull.* **2005**, *26*, 166.
36. Oluwaniyi, O.; Dosumu, O.; Awolola, G. Effect of local processing methods (boiling, frying and roasting) on the amino acid composition of four marine fishes commonly consumed in Nigeria. *Food Chem.* **2010**, *123*, 1000–1006. [[CrossRef](#)]
37. Yamakado, M.; Tanaka, T.; Nagao, K.; Imaizumi, A.; Komatsu, M.; Daimon, T.; Miyano, H.; Tani, M.; Toda, A.; Yamamoto, H.; et al. Plasma amino acid profile associated with fatty liver disease and co-occurrence of metabolic risk factors. *Sci. Rep.* **2017**, *7*, 14485. [[CrossRef](#)]
38. Lan, C.; Zhao, Y.Q.; Li, X.R.; Wang, B. High Fischer ratio oligopeptides determination from Antarctic krill: Preparation, peptides profiles, and in vitro antioxidant activity. *J. Food Biochem.* **2019**, *43*, e12827. [[CrossRef](#)]
39. Shi, T.; Li, Y. Producing high Fischer ratio peptides from milk protein and its application in infant formula milk powder. *Qual. Assur. Saf. Crops Foods* **2021**, *13*, 49–58. [[CrossRef](#)]
40. Wang, Z.; Zhang, X.; Wang, L.; Ou, X.; Huang, J. High Fischer ratio oligopeptides in food: Sources, functions and application prospects. *J. Future Foods* **2024**, *4*, 128–134. [[CrossRef](#)]
41. Friedman, M. Nutritional value of proteins from different food sources. A review. *J. Agric. Food Chem.* **1996**, *44*, 6–29. [[CrossRef](#)]
42. Chen, J.; Liu, H. Nutritional indices for assessing fatty acids: A mini-review. *Int. J. Mol. Sci.* **2020**, *21*, 5695. [[CrossRef](#)] [[PubMed](#)]
43. Torrinha, A.; Cruz, R.; Gomes, F.; Mendes, E.; Bandarra, N.M.; Nunes, M.L. Octopus lipid and vitamin E composition: Interspecies, interorigin, and nutritional variability. *J. Agric. Food Chem.* **2014**, *62*, 8508–8517. [[CrossRef](#)] [[PubMed](#)]
44. Zula, A.T.; Desta, D.T. Fatty Acid-Related Health Lipid Index of Raw and Fried Nile Tilapia (*Oreochromis niloticus*) Fish Muscle. *J. Food Qual.* **2021**, *2021*, 6676528. [[CrossRef](#)]
45. Fernandes, C.E.; da Silva Vasconcelos, M.A. Nutritional and lipid profiles in marine fish species from Brazil. *Food Chem.* **2014**, *160*, 67–71. [[CrossRef](#)]
46. Patted, P.G.; Masareddy, R.S.; Patil, A.S. Omega-3 fatty acids: A comprehensive scientific review of their sources, functions and health benefits. *Future J. Pharm. Sci.* **2024**, *10*, 94. [[CrossRef](#)]
47. Ghasemi Fard, S.; Wang, F.; Sinclair, A.J. How does high DHA fish oil affect health? A systematic review of evidence. *Crit. Rev. Food Sci. Nutr.* **2019**, *59*, 1684–1727. [[CrossRef](#)]
48. Gonçalves, J.M.S.; Monteiro, P.; Oliveira, F.; Afonso, C.M.L.; Rangel, M.; Milla, D.; Henriques, N.S.; Sousa, I.; Bentes, L. *Biodiversidade Marinha do Sublitoral Entre a Ponta da Piedade e a Praia do Barranco*; Universidade do Algarve, CCMAR: Faro, Portugal, 2015; p. 104.
49. Gonçalves, J.M.S.; Monteiro, P.; Afonso, C.; Almeida, C.; Oliveira, F.; Rangel, M.; Ribeiro, J.; Machado, M.; Veiga, P.; Abecasis, D.; et al. *Cartography and Characterization of the Marine Communities off the National Underwater Ecological Reserve Between the Arade River and Ponta da Piedade*; Final Report; ARH Algarve: Faro, Portugal, 2010; 122p.

50. Gonçalves, J.M.S.; Monteiro, P.; Afonso, C.; Conduto, T.; Almeida, C.; Machado, M.; Oliveira, F.; Bentes, L.; Erzini, K. *Caracterização de Referência Biológica de Áreas de Exploração de Inertes Subtidais de Quarteira*; Universidade do Algarve, CCMAR: Faro, Portugal, 2008; p. 50.
51. Gonçalves, J.M.S.; Afonso, C.M.L.; Mateus, M.A. *Avaliação da Recuperação Biológica das Manchas de Empréstimo de Vale do Lobo e Albufeira Resultantes das Dragagens*; CCMAR: Faro, Portugal, 2021; p. 49.
52. Ford, A.H.; Almeida, O.P. Effect of homocysteine lowering treatment on cognitive function: A systematic review and meta-analysis of randomized controlled trials. *J. Alzheimers Dis.* **2012**, *29*, 133–149. [[CrossRef](#)]
53. Alba-Preciado, M.A.; Leyva-Morales, J.B.; Granados-Amores, J.; García-Hernández, J.; Aguilera-Márquez, D.; de Jesús Bastidas-Bastidas, P.; Zamora-Arellano, N.Y.; Abelardo González-Ramírez, C.A.; Granados-Amores, A.; Dueñas-Romero, J. Distribution and health risk assessment of heavy metals in the octopus (*Octopus hubbsorum*) in the Mexican Pacific. *Food Chem. Toxicol.* **2025**, *200*, 115362. [[CrossRef](#)]

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