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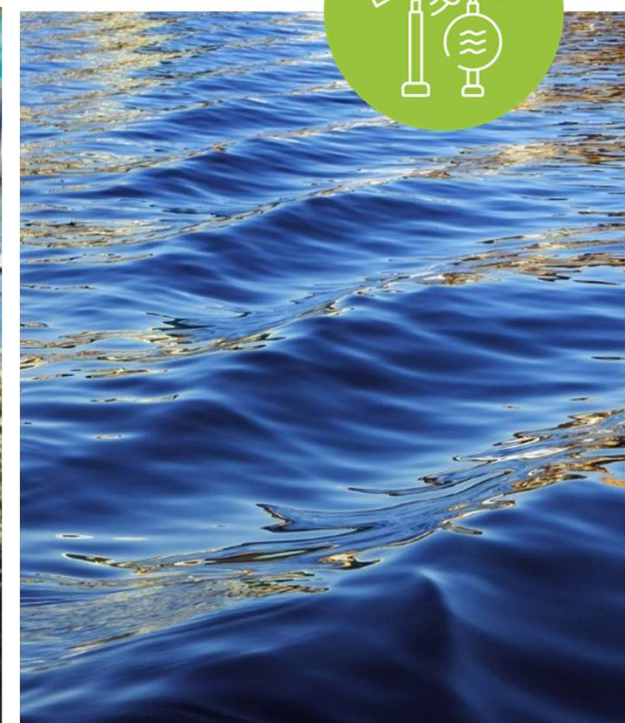
AQUAFISH



Vers une valorisation durable des produits de la mer

AQUACULTURE & FISHERIES 0.0

16 avril 2026



What are the key food security considerations and risks associated with these products?

Cláudia Afonso



Activity 2.2
Food security and risk
assessment

Objectives



This activity aims to carry out a food safety and risk assessment associated with the consumption of new products developed in WP1

Evaluation of dietary recommendations for the effective consumption of the developed products:

- **Functional products:** Mackerel burger, seaweed-based nachos, and mackerel-based sauce
- **Seafood-based products:** Tuna pâté (zurrapa), energy bar, and holothurian powder

Seafood: Benefits&Hazardous/Risks

Seafood is recommended in a balanced diet not only for the diversity of species, but also for the important health benefits to consumers



- Proteins of high biological value
- Lipids (EPA+DHA, n-3 PUFA, etc)
- Essential elements (Se, I, etc)
- Vitamins (B1, B12, D, E, etc)
- Carbohydrates
- Biological activities,
- Etc.

- Beneficial effects on cognitive and visual development;
- Lowering the risk of coronary heart disease and stroke;
- Prevention/reduction of multiple other adverse health outcomes



Seafood can also accumulate toxic compounds - Dioxins, Lead (Pb), Arsenic (AsT, iAs), Cadmium (Cd), Mercury (HgT, MeHg), etc

Mutagenicity, Carcinogenicity, Genotoxicity, etc



Adverse effects upon human health



How to assess the risks and benefits arising from the Seafood consumption?



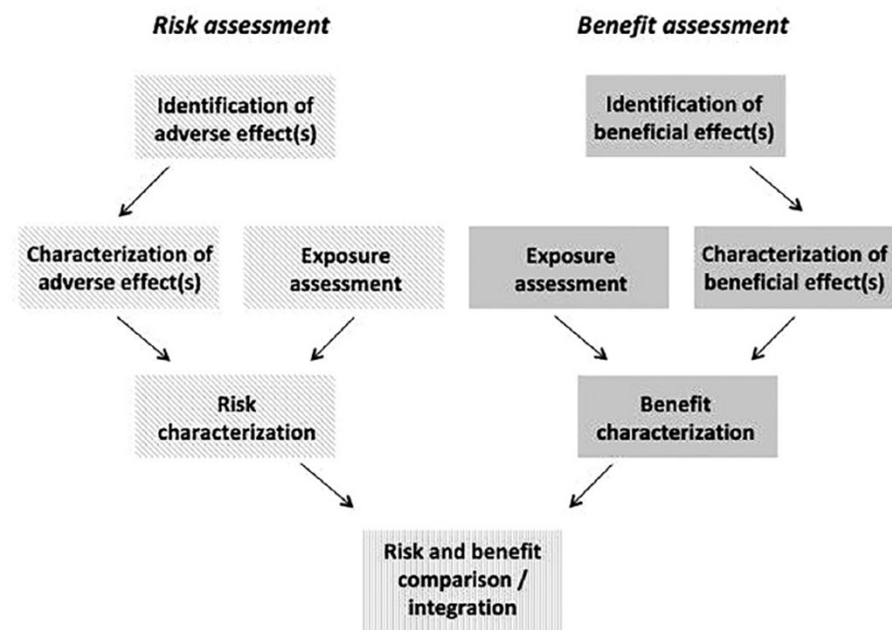
- Identify main hazards and benefits worthy of study

Collect nutritional, toxicological & medical data

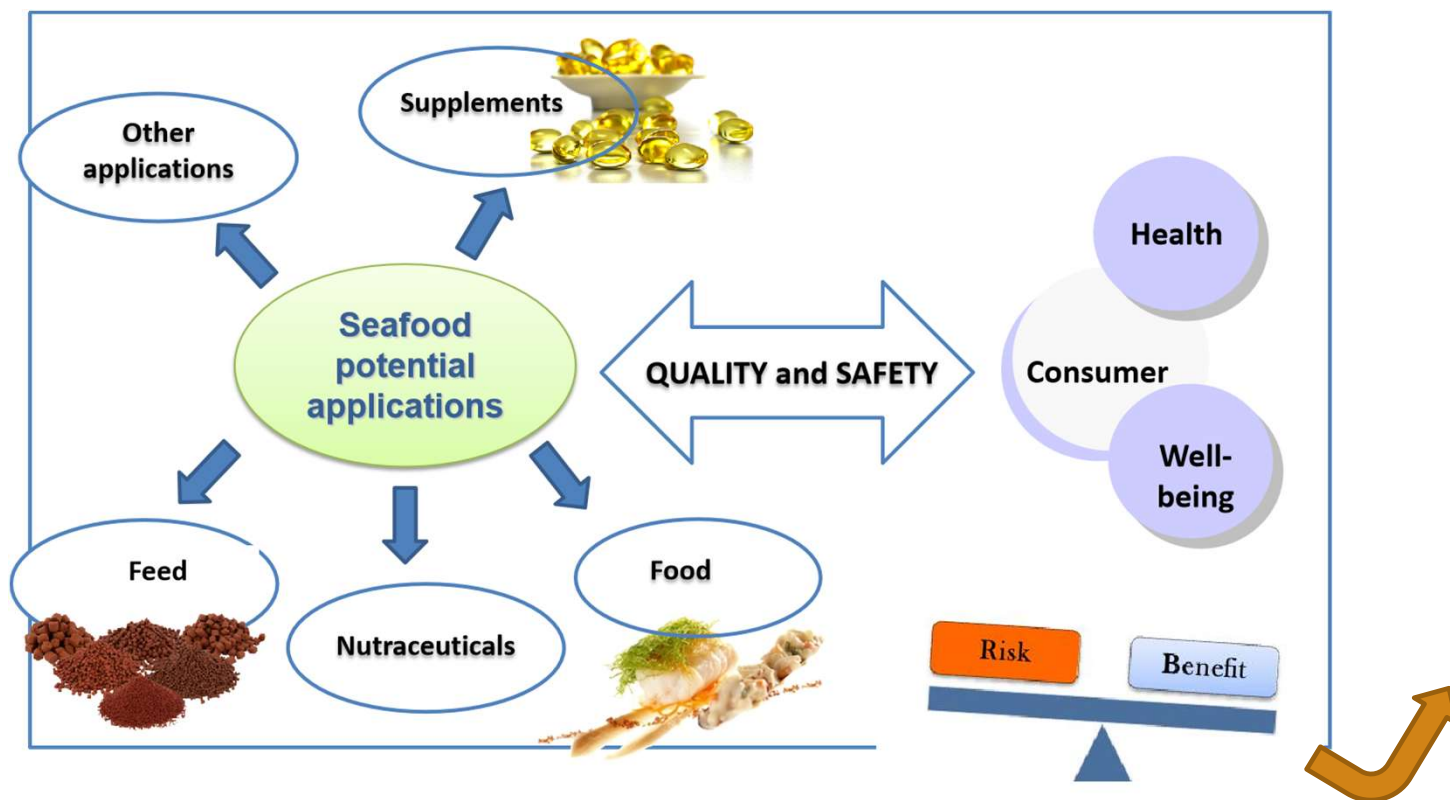
- Apply a probabilistic approach to quantify probability of exceeding thresholds

Combine contents with consumption data, consumption frequency, scenarios or surveys)

- Compare and balance probabilities of exposure to hazards and attainment of benefits



Seafood functional products are developed having the future of human food in mind



Compounds
lipids, polyphenols, essential elements, contaminants, etc.

Biological Activities
Anti-inflammatory, antioxidant, cytotoxicity, anti-hypercholesterolemic potential, etc.

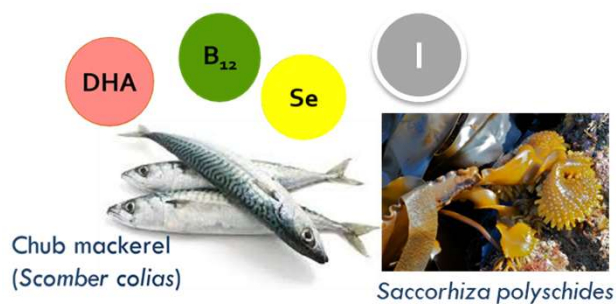
Bioaccessibility and bioavailability studies

Case-studies of seaweed-based functional foods



Portuguese Institute for Sea and Atmosphere

Undervalued and nutritious species

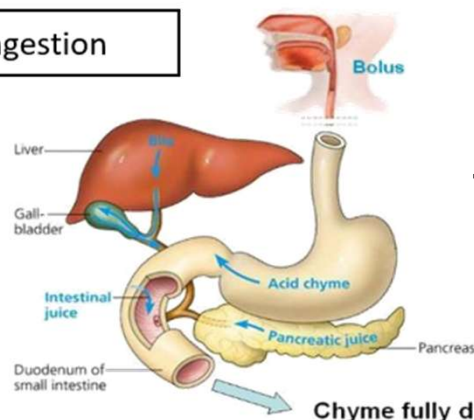


Product rich in neuroprotective nutrients with the potential to prevent and/or delay cognitive decline associated with aging, such as Alzheimer's disease.

Culinary treatment

- Steamed
- Roasted
- Grilled

Food ingestion



Bioaccessibility of a compound is the amount available for intestinal absorption

Chyme fully digested



Afonso et al., 2015

Case-studies of seaweed-based functional foods



Portuguese Institute for Sea and Atmosphere

Table 3
 Elemental composition (in mg/kg dw) of the harvested in the wild, land-based cultivated, and open sea cultivated *Saccorhiza polyschides* biomass before and after digestion.

Element	Initial vs Bioaccessible	Wild <i>Saccorhiza polyschides</i>	Cultivated <i>Saccorhiza polyschides</i>		
			Land-Based		Open Sea
		October	February	March	July
As (mg/kg dw)	Initial	17.5 ± 0.3 ^{aA}	15.5 ± 0.6 ^{bA}	14.3 ± 0.2 ^{cA}	15.8 ± 0.1 ^{bA}
	Bioaccessible	10.4 ± 0.2 ^{aB}	10.7 ± 0.4 ^{aB}	9.5 ± 0.1 ^{bB}	9.4 ± 0.1 ^{bB}
Se (mg/kg dw)	Initial	1.07 ± 0.05 ^a	1.65 ± 0.14 ^b	1.79 ± 0.10 ^b	1.16 ± 0.00 ^a
	Bioaccessible	<LOQ	<LOQ	<LOQ	<LOQ
Cd (mg/kg dw)	Initial	0.60 ± 0.01 ^{bA}	0.07 ± 0.00 ^{dA}	0.26 ± 0.00 ^{cA}	1.11 ± 0.01 ^{aA}
	Bioaccessible	0.16 ± 0.00 ^{bB}	0.01 ± 0.00 ^{dB}	0.04 ± 0.00 ^{cB}	0.29 ± 0.00 ^{aB}
I (mg/kg dw)	Initial	522 ± 7 ^{aA}	391 ± 12 ^{bA}	497 ± 24 ^{aA}	367 ± 6 ^{bA}
	Bioaccessible	260 ± 3 ^{aB}	159 ± 5 ^{cB}	145 ± 7 ^{dB}	183 ± 3 ^{BB}
Hg (mg/kg dw)	Initial	0.008 ± 0.003 ^a	0.010 ± 0.000 ^a	0.012 ± 0.000 ^a	<LOQ ^b
	Bioaccessible	<LOQ	<LOQ	<LOQ	<LOQ
Pb (mg/kg dw)	Initial	0.58 ± 0.01 ^{bA}	1.00 ± 0.01 ^{dA}	0.92 ± 0.06 ^{cA}	0.13 ± 0.00 ^{aA}
	Bioaccessible	0.017 ± 0.000 ^{aB}	0.013 ± 0.000 ^{bB}	0.007 ± 0.000 ^{cB}	0.001 ± 0.001 ^{dB}



Saccorhiza polyschides

Farming a wild seaweed and changes to its composition, bioactivity, and bioaccessibility: The *Saccorhiza polyschides* case study

C. Cardoso^{a,b,*}, J. Almeida^{a,c}, I. Coelho^d, I. Delgado^d, R. Gomes^a, R. Quintã^e, N.M. Bandarra^{a,b}, C. Afonso^{a,b}

- *S. polyschides* is a good source of I
- Bioaccessibility of Iodine is 30 - 50 %



Table Z - Risk-benefit assessment through quantification of threshold-exceeding probability (%) for seaweed consumption based on scenarios and taking into account the iodine content.

Seaweed Species	Iodine															Sample Dimension
	1 meal/year			1 meal/month			1 meal/week			2 meals/week			3 meals/week			
	UL (1100 µg/day)	UL (600 µg/day)	AI (150 µg/day)	UL (1100 µg/day)	UL (600 µg/day)	AI (150 µg/day)	UL (1100 µg/day)	UL (600 µg/day)	AI (150 µg/day)	UL (1100 µg/day)	UL (600 µg/day)	AI (150 µg/day)	UL (1100 µg/day)	UL (600 µg/day)	AI (150 µg/day)	
Green Seaweed	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	1.08×10 ⁻⁷	2.91×10 ⁻⁴	7.82×10 ⁻⁵	1.42×10 ⁻³	1.09	2.79×10 ⁻⁴	2.17×10 ⁻²	9.58	2.30×10 ⁻²	0.28	19.11	50
<i>Ulva</i> sp.	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	8.00×10 ⁻³	4.00×10 ⁻⁵	1.19×10 ⁻³	2.64	1.27×10 ⁻⁵	1.69×10 ⁻³	12.15	36
Red Seaweed	2.51×10 ⁻³	6.71×10 ⁻³	6.34×10 ⁻²	<1.0×10 ⁻⁸	0.36	3.17	1.55	3.62	18.34	4.96	9.27	31.64	7.84	14.79	41.43	87
Brown Seaweed	0.09	0.24	2.41	8.44	8.76	30.38	19.8	31.12	63.68	33.77	47.43	77.92	42.62	56.94	84.21	315
<i>Alaria esculenta</i>	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	59.39	<1.0×10 ⁻⁸	18.67	85.72	59.97	83.8	99.75	30
<i>Fucus</i> sp.	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	1.62×10 ⁻⁸	1.32×10 ⁻⁶	3.09×10 ⁻²	5.01×10 ⁻⁴	4.56×10 ⁻²	37.92	6.33×10 ⁻²	9.99	77.25	1.55	19.80	88.33	38
<i>Laminaria</i> sp.	<1.0×10 ⁻⁸	1.03×10 ⁻⁷	3.40×10 ⁻²	8.34	23.82	83.68	68.47	85.34	97.59	86.8	94.1	99.00	92.20	96.27	99.25	69
<i>Saccharina</i> sp.	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	6.23×10 ⁻⁶	6.21×10 ⁻⁴	3.36	81.13	57.58	83.54	97.57	85.56	94.05	98.84	92.12	96.2	99.09	62
<i>Saccharina latissima</i>	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	8.65×10 ⁻⁴	6.37×10 ⁻²	4.62	83.76	59.25	85.26	97.62	87.64	94.62	99.05	93.20	96.86	99.11	51
<i>Undaria</i> sp.	6.76×10 ⁻⁷	3.60×10 ⁻⁶	1.65×10 ⁻⁴	1.67×10 ⁻⁴	1.15×10 ⁻³	9.36×10 ⁻²	1.68×10 ⁻²	0.12	9.89	0.18	1.14	52.76	0.59	3.69	76.14	38
<i>Undaria pinnatifida</i>	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	<1.0×10 ⁻⁸	4.57×10 ⁻⁷	2.32×10 ⁻⁵	4.49×10 ⁻⁶	7.69×10 ⁻⁴	8.63	1.75×10 ⁻³	0.23	41.27	0.06	4.33	62.33	36

Calculated probability of exceeding the Iodine UL [P(Xi>AI or UL), %]. Considering for Iodine the UL of 1100 µg/day (NRC, 2000), 600 µg/day (EFSA, 2006) and the AI of 150 µg/day (EFSA, 2014). Values in bold correspond to probabilities calculated through the 'plug-in' (PI) estimator.

It is important to know & quantify the risk-benefit balance



Issuance of Dietary Recommendations

Healthy recipes based on sustainable, safe, tasty and nutritious seafood



Portuguese Institute for Sea and Atmosphere

Table 6 - Selenium and iodine content (expressed in µg/100 g ww or, in the case of seaweed, µg/100g dw) in the initial and bioaccessible samples of the ingredients (chub mackerel, boiled quinoa, and the seaweed *Saccorhiza polyschides*) and hamburgers (raw and cooked) and respective elemental bioaccessibility percentage.

Element		Ingredient			Hamburger			
		Raw chub mackerel	Quinoa (boiled)	Seaweed <i>Saccorhiza polyschides</i> (freeze-dried)*	Raw	Steamed	Roasted	Grilled
Se	Initial (µg/100 g)	59 ± 4 ^A	1.1 ± 0.1 ^A	116 ± 0	48 ± 2 ^{aA}	50 ± 4 ^{hA}	54 ± 3 ^{hA}	61 ± 5 ^{bA}
	Bioacc. (µg/100 g)	47 ± 3 ^B	0.08 ± 0.01 ^B	<LOQ	38 ± 1 ^{aB}	41 ± 3 ^{hB}	46 ± 4 ^{hB}	43 ± 2 ^{aB}
	Bioaccessibility (%)	80 ± 0 ^h	7 ± 0 ^h	<LOQ	80 ± 10 ^h	82 ± 13 ^h	85 ± 5 ^h	70 ± 0 ^h
I	Initial (µg/100 g)	25 ± 1 ^A	<LOQ	36720 ± 603 ^A	224 ± 7 ^{aA}	221 ± 2 ^{aA}	232 ± 16 ^{hA}	255 ± 6 ^{bA}
	Bioacc. (µg/100 g)	19 ± 1 ^B	ND	17586 ± 289 ^B	127 ± 4 ^{aB}	153 ± 1 ^{hB}	163 ± 11 ^{hB}	153 ± 4 ^{hB}
	Bioaccessibility (%)	78 ± 0 ^h	ND	48 ± 3 ^f	57 ± 1 ^x	69 ± 2 ^h	70 ± 1 ^h	60 ± 2 ^x

Hamburger enriched in *S. polyschides*



I Bioaccessible

153 µg/100g (102 % DRV)

Nutritional information			
Steamed Hamburger			
Dose/100 g			
			% DRV
Calories	kcal	140	
Fat	kcal	51	
Protein	kcal	73	
Fat	g	5,65	
DHA	mg	1234	494
Protein	g	18.3	40**
** Considering AR of 0.66 g per body weight (EFSA) and a 70 kg adult			
Essential elements			
Selenium	µg	50	71-91*
Iodine	µg	221	147*

DRV - Dietary Reference Value *EFSA-IOM

Case-studies of seaweed-based functional foods

The composition and properties of this functional food were thoroughly study as well as their stability over storage time



Article

Mackerel and Seaweed Burger as a Functional Product for Brain and Cognitive Aging Prevention

Carlos Cardoso ^{1,2,*}, Jorge Valentim ^{2,3}, Romina Gomes ^{2,4}, Joana Matos ^{2,4}, Andreia Rego ⁵, Inês Coelho ⁵, Inês Delgado ⁵, Carla Motta ⁵, Isabel Castanheira ⁵, José A. M. Prates ^{6,7}, Narcisca M. Bandarra ^{1,2} and Cláudia Afonso ^{1,2}

Heliyon 10 (2024) e27171



Research article

Influence of cooking methods and storage time on colour, texture, and fatty acid profile of a novel fish burger for the prevention of cognitive decline

Jorge Valentim ^{a,b}, Cláudia Afonso ^{b,c}, Romina Gomes ^{b,d}, Ana Gomes-Bispo ^{b,c}, José A.M. Prates ^{e,f}, Narcisca M. Bandarra ^{b,c}, Carlos Cardoso ^{b,e,f}

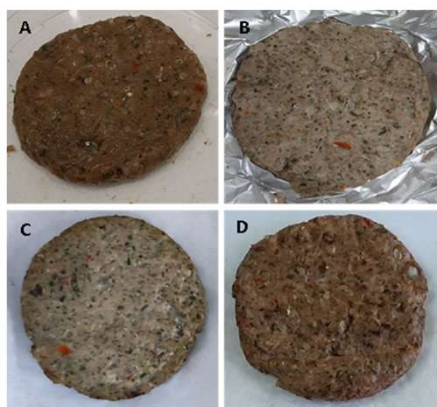


Fig. 1. The prepared fish hamburgers (A: raw; B: steamed; C: roasted; and D: grilled).

Organoleptic study ✓

- Color.
- Odor.
- Texture.
- Other physical properties.
- Presence/Absence of mold.

Food risk assessment: Microbiological → Raw materials selected from WP1.

Microbiological validation

- *Count of aerobic microorganisms.*
- *Count of Enterobacteriaceae.*
- *Presence/Absence of Escherichia coli.*
- *Presence/Absence of Salmonella spp.*
- *Presence/Absence of Listeria monocytogenes*

Objective:

Ensure the food safety and hygiene of the raw material acquisition processes

Case-studies: Tuna pate (zurrapa)

Organoleptic study

Microbiological validation raw material:

Parameter	Result (cfu/g)	Unit	Limits
<i>Salmonella</i> spp	Not detected	-	-
<i>Listeria monocytogenes</i>	Not detected	-	Not detected
<i>Escherichia coli</i>	Not detected	-	-
Enterobacteria	<1.00E+01	cfu/g	-
Aerobes	<1.00E+02	cfu/g	-

Table 1. Microbiological validation of fish cooking water.

Parameter	Value	Unit
Energy value	746	KJ/100g
	176	Kcal/100g
Crude protein	43.00	g/100g
Fats	<1.00	g/100g
Saturated fats	0.06	g/100g
Carbohydrates	<2.00	g/100g
Total sugars	<1.00	g/100g
Salt	5.90	g/100g

Table 3. Nutritional composition of tuna mojama trimmings.

Parameter	Value	Unit
Energy value	17	KJ/100g
	4	Kcal/100g
Moisture	93.5	g/100g
Crude protein	1.0	g/100g
Fats	<0.5	g/100g
Carbohydrates	<0.5	g/100g
Total sugars	<0.5	g/100g
Total fiber	<1.0	g/100g
Ash	5.5	g/100g
Salt	5.8	g/100g
Sodium	2.3	g/100g
pH	6.1	pH units

Table 2. Nutritional composition of fish cooking water.

Microbiological validation product: awaiting microbiological results from storage over an extended period of time

TUNAPÂTÉ		
Ingredients	Quantity (g)	Quantity (%)
Fish cooking water	218	19.6
Mineral water	382	34.4
Soy lecithin	60	5.4
Almond flour	120	10.8
Sodium alginate	30	2.7
Tuna mojama trimmings	300	27.0
TOTAL	1110	100.0

Table 4. Formulation of tuna pâté.

Parameter	Result (cfu/g)	Unit	Limits
<i>Clostridium botulinum</i>	Not detected	-	Not detected
<i>Salmonella</i> spp	Not detected	-	Not detected
<i>Listeria monocytogenes</i>	Not detected	-	Not detected
<i>Escherichia coli</i>	Not detected	-	Not detected
Enterobacteriae	<1.00E+01	cfu/g	-
Aerobes	1.40E+04	cfu/g	-

Table 5. Microbiological validation of tuna pâté.

Parameter	Value	Unit
Energy value	968	KJ/100g
	232	Kcal/100g
Moisture	55.70	g/100g
Crude protein	10.30	g/100g
Fats	14.00	g/100g
Carbohydrates	15.70	g/100g
Total sugars	1.10	g/100g
Total fiber	1.00	g/100g
Ash	3.30	g/100g
Salt	1.76	g/100g
Sodium	0.70	g/100g

Table 6. Nutritional composition of tuna pâté.

Parameter	Value	Unit
Saturated fatty acids	2.20	g/100g
Butyric acid (C:4:0)	<0.1	%
Caproic acid (C:6:0)	<0.1	%
Caprylic acid (C:8:0)	<0.1	%
Capric acid (C:10:0)	<0.1	%
Undecanoic acid (C:11:0)	<0.1	%
Lauric acid (C:12:0)	<0.1	%
Tridecanoic acid (C:13:0)	<0.1	%
Myristic acid (C:14:0)	0.2	%
Pentadecanoic acid (C:15:0)	0.1	%
Palmitic acid (C:16:0)	12.1	%
Margaric acid (C:17:0)	0.1	%
Stearic acid (C:18:0)	2.7	%
Arachidic acid (C:20:0)	0.2	%
Heineicosanoic acid (C:21:0)	<0.1	%
Behenic acid (C:22:0)	0.2	%
Tricosanoic acid (C:23:0)	0.1	%
Lignoceric acid (C:24:0)	0.1	%
Monounsaturated fatty acids	8.22	g/100g
Myristoleic acid (C:14:1)	<0.1	%
Pentadecenoic acid (C:15:1)	<0.1	%
Palmitic acid with isomer (C:16:1)	0.9	%
Margaroleic acid (C:17:1)	0.1	%
Oleic acid with isomer (C:18:1)	57.1	%
Gondoic acid (C:20:1)	0.2	%
Erucic acid (C:22:1n9)	0.1	%
Nervonic acid (C:24:1n9)	0.2	%
Polyunsaturated fatty acids	3.58	g/100g
Linoleic acid with isomer (C:18:2)	23.2	%
Linolenic acid with isomer (C:18:3)	1.1	%
Linolenic acid (C:18:3n3)	1.1	%
Gamma-linolenic acid (C:18:3n6)	<0.1	%
Stearidonic acid (C:18:4n3)	0.1	%
Eicosadienoic acid (C:20:2n6)	<0.1	%
Dihomo-gamma-linolenic acid (C:20:3n6)	<0.1	%
Arachidonic acid (C:20:4n6)	0.1	%
Eicosatrienoic acid (C:20:3n3)	<0.1	%
Eicosatetraenoic acid (C:20:4n3)	<0.1	%
Eicosapentaenoic acid (EPA) (C:20:5n3)	0.2	%
Docosadienoic acid (C:22:2n6)	<0.1	%
Docosapentaenoic acid (DPA) (C:22:5n3)	0.1	%
Cervonic acid (DHA) (C:22:6n3)	0.9	%

Table 7. Fatty acids profile of tuna pâté.

Case-studies: Fish seasoning

ctaqua

CENTRO TECNOLÓGICO DE LA ACUICULTURA

Organoleptic study

Microbiological validation raw material:

Parameter	Result	Unit	Limits
<i>Salmonella</i> spp	Not detected	-	Not detected
<i>Listeria monocytogenes</i>	Not detected	-	Not detected
<i>Escherichia coli</i>	Not detected	-	-
Enterobacteria	<1.00E+01 ± 0.00E+00	cfu/g	1.00E+03
Aerobes	1.07E+03 ± 5.77E+01	cfu/g	1.00E+06

Table 2. Microbiological validation of fresh anchovy.

Parameter	Value	Unit
Moisture	76.0 ± 0.7	g/100g
Crude protein	20.7 ± 0.8	g/100g

Table 3. Nutritional composition of fresh anchovy.

Ingredients	Quantity (g)	Quantity (%)
Fresh anchovy	15000	100.00
TOTAL	15000	100.00

Table 4. Formulation of anchovy seasoning.

Microbiological validation product: awaiting microbiological results from storage over an extended period of time

Parameter	Result	Unit	Limits	Where
Histamines	21.9 ± 4.1	mg/kg	Mean ≤ m Maximum of c/n values between m and M No values higher than M	m=100 mg/kg n=9; c=2 M=200 mg/kg
<i>Salmonella</i> spp	Not detected	-	Not detected	-
<i>Listeria monocytogenes</i>	Not detected	-	Not detected	-
<i>Escherichia coli</i>	Not detected	-	Not detected	-
Enterobacteria	<1.00E+01 ± 0.00E+00	cfu/g	1.00E+02	-
Aerobes	1.13E+03 ± 1.15E+02	cfu/g	1.00E+05	-
Total volatile basic nitrogen	95 ± 6	mg/100g	200	-

Table 5. Microbiological validation of anchovy seasoning.

Parameter	Value	Unit
Energetic value	1680 ± 17	KJ/100g
	398 ± 4	Kcal/100g
Moisture	1.13 ± 0.12	g/100g
Crude protein	76.03 ± 0.65	g/100g
Total fats	10.43 ± 0.15	g/100g
Saturated fatty acids	3.35 ± 0.02	g/100g
Monounsaturated fatty acids	2.24 ± 0.02	g/100g
Polyunsaturated fatty acids	4.85 ± 0.16	g/100g
Carbohydrates	<0.5 ± 0.0	g/100g
Total sugars	<0.5 ± 0.0	g/100g
Ash	11.43 ± 0.68	g/100g
Salt	0.939 ± 0.021	g/100g
Sodium	0.376 ± 0.009	g/100g
pH	5.80 ± 0.10	pH units
Phosphorus	25100 ± 1552	mg/kg
Calcium	9941 ± 1368	mg/kg

Table 6. Nutritional composition of anchovy seasoning.

Parameter	Value	Unit
Aspartic acid	5.4 ± 0.6	%
Glutamic acid	6.9 ± 0.9	%
Serine	3.0 ± 0.3	%
Histidine	3.2 ± 0.3	%
Glycine	3.4 ± 0.2	%
Threonine	1.7 ± 0.4	%
Arginine	3.1 ± 0.3	%
Alanine	4.6 ± 0.4	%
Tyrosine	1.9 ± 0.3	%
Cystine	<0.02 ± 0.0	%
Valine	1.3 ± 0.4	%
Methionine	2.8 ± 0.3	%
Phenylalanine	2.2 ± 0.4	%
Isoleucine	1.2 ± 0.5	%
Leucine	4.7 ± 0.8	%
Lysine	5.9 ± 1.0	%
Proline	<0.02 ± 0.0	%
Tryptophan	1.1 ± 0.3	%
Hydroxyproline	<0.02 ± 0.0	%

Table 7. Amino acids profile of anchovy seasoning.

Key message:



Culinary treatment + bioaccessibility → essential for **risk–benefit assessment**
Improves evaluation of seafood nutritional value



Supports recommendations on cooking practices and dietary choices

Outcome: Promotion of human health and well-being

Microbiology: Safe, stable, and suitable for consumption

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Thank you
Obrigada
Go raibh maith agat
Merci
Gracias

