MusselsAlive Report

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MEAT QUALITY OF ROPE GROWN IRISH MUSSELS – SPRING 2011

This report describes the work developed at IPIMAR in order to characterize the meat quality of rope grown mussels from Ireland.

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Meat quality of rope grown mussels in Ireland – Spring 2011

The work developed at IPIMAR aimed to characterize the meat quality of rope grown mussels from Ireland in order to evaluate the current status of mussel's quality provided to European consumers throughout the year. So far, one season has been sampled and evaluated: mussel harvested in Spring were shipped from Ireland (June 2011) and received at INRB, I.P./L-IPIMAR, (1st of July 2011). Once in Portugal mussels were immediately examined and several parameters were checked, namely:

1. Transport box and net bags
2. Biometry
3. Mortality
4. Sensorial analyses of raw and cooked mussels performed by a professional panel
5. Edible meat content
6. The remaining edible meat of mussels was homogenised and frozen for further chemical analyses.

This report is divided in three main sections. The first is the ***Transport Conditions*** and comprehends the parameters one to three from the above list. The second part describes the results of the sensorial analyses and the edible content and is entitled ***Perceived Freshness***. Finally, the results of the chemical analyses, including proteins, fat, glycogen, ash, moisture, fatty acids, amino acids and inorganic elements are shown in the third section - ***Chemical Composition***.

TRANSPORT CONDITIONS

1.1 Transport box

Mussels were packed in 10 net bags. Each net bag had 1123.7 ± 22.1 g, corresponding to 100 ± 9 mussels each. The bags were transported in a *Styrofoam* box as shown in Figure 1.

Figure 1. Transport box containing the mussels' net bags (outer and inner views).

To keep a moist environment and the temperature low, the net bags were covered with wet journal paper and the bottom of the styrofoam box had a layer of packed ice, followed by an insulating plastic layer (see figure bellow). However, at arrival the ice was almost completely melted, being the mussels immersed in water and inter-valvar liquid.

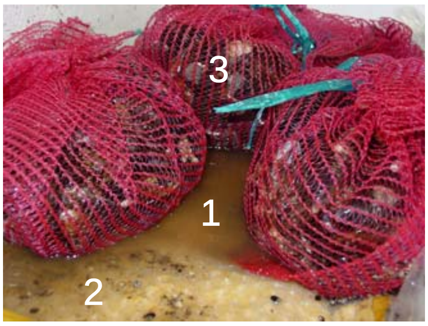

Figure 1. A - The different layers wrapping the net bags of Spring mussels. 1 – Melted ice and inter-valve liquid; 2- Insulating plastic layer; 3 –Net bag with live mussels.

1.2 Net bags

Each net bag was visually inspected and smell was characterized using a modified scale from Pastoriza *et al.* (2004). Six class scales were used:

1. Characteristic sea, fresh smell
2. Less characteristic, faded sea smell
3. Neutral
4. Slightly to ammonia
5. Ammonia
6. Very unpleasant

Despite the smell clearly characteristic and fresh, the panellists could also detect a strong plastic odour from the type of net bags used to transport mussels. Five out of 10 net bags had broken shells (around 1% of the whole Spring sample received).

1.3 Mortality

Mortality was very low in all bags, being 0% in 5 net bags and registering a maximum of 3.3% of dead mussels upon arrival at Lisbon, Portugal (Figure 3; average mortality= 0.9 ± 1.3).

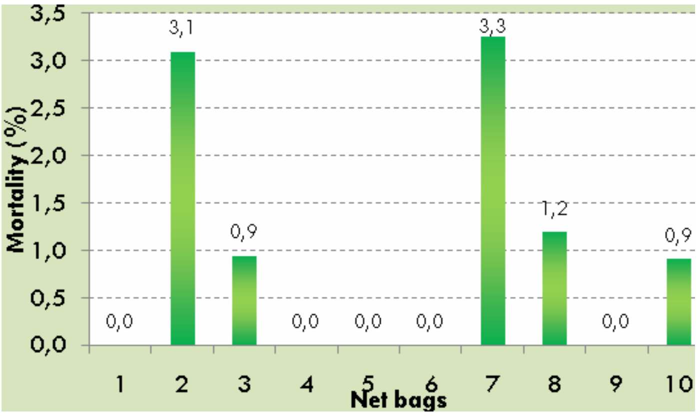

Figure 2. Mortality in each net bag after transport from Ireland in a Styrofoam box.

> *In general, beside the clearly characteristic sea, fresh smell, a strong plastic odour was detected in all net bags. Upon arrival at Lisbon, only 1% of the sample had broken shells and the average mortality was 0.9 ± 1.3.*

2. PERCEIVED FRESHNESS

2.1 Sensorial analysis of live and cooked mussels

Ten experienced panellists analysed the appearance of the shell and the smell of live mussels harvested in Spring. The same panel also scored the colour, odour, shell filling, flavour, texture and succulence of steamed-cooked mussels. For each treatment (live and cooked) a global rate was attributed to the mussels. Three mussels were analysed per treatment, in a total of thirty live mussels and thirty steamed-cooked mussels.

2.1.2. LIVE MUSSELS SENSORIAL ANALYSIS

The scale used to characterize live mussels is indicated in table 1.

Table 1. Scale for sensorial evaluation of live mussels.

	1	2	3	4	5	6
Shell appearance	Closed, cleaned	Closed, dirty (algae, mud)	Open, cleaned	Open, dirty		
Shell Odour	Characteristic sweet fresh	Non-specific slightly sweet	Neutral	Slightly to ammonia	Ammonia	Very unpleasant
Global Rate	Very Good	Good	Acceptable	Rejected		

Most panellists reported that live mussels harvested in Spring had closed and dirty shells (70%), i.e. with mud, algae, *bissus* or barnacles, whereas the remaining 30% panellists classified the mussels shells as closed and cleaned (see Figure 4). The smell was generally characteristic (70 %), however 20% panellists referred a non specific (20 %) or neutral (10%) odour. The global rate varied from good (70 %) to acceptable (30 %), mostly due to shell appearance (dirtiness).

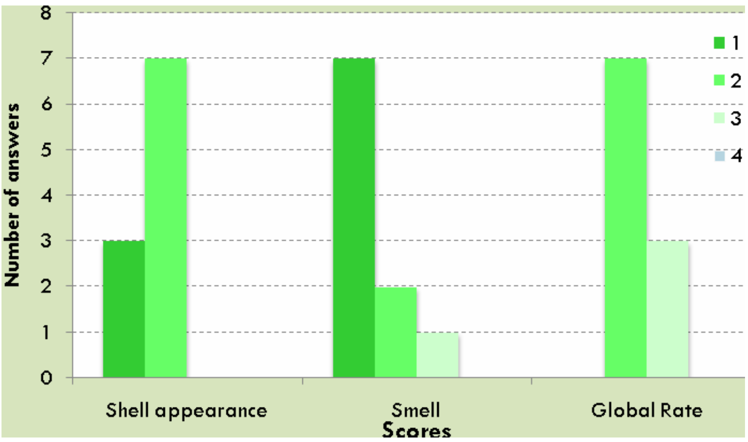

Figure 3. Scores attributed to live mussels harvested in Spring (shell appearance, smell and global rate). The number of panellists answers is evidenced according to the scale classes used (see table 1) represented by the colour coded bars.

2.1.2. STEAM-COOKED MUSSELS SENSORIAL ANALYSES

Mussels were also steam-cooked at 100 °C for 3 min and served as two valves to trained panellists at approximately 35 °C. The scale used to characterize steamed cooked mussels is indicated in table 2.

Table 2. Scale for sensory evaluation of steam-cooked mussels (adapted from Pastoriza *et al.*, 2004).

	1	2	3	4	5	6
Colour	Uniform, bright	Uniform pale	Non uniform, bright	Non uniform, pale		
Odour	Characteristic sweet fresh	Non-specific slightly sweet	Neutral	Slightly to ammonia	Ammonia	Very unpleasant
Shell filling	Meaty	Less meaty	Sparse	Very Sparse		
Taste	Characteristic mild	Characteristic slightly mild	Strong	Slightly sour	Sour	Sickening
Texture	Very firm	Firm	Slightly firm	Slightly soft	Soft	Very soft
Succulence	Juicy	Less juicy	Dry	Very dry		
Global Rate	Very Good	Good	Acceptable	Rejected		

As shown in Figure 5, Spring cooked mussels were ranked as very good (20 %), good (70 %) and acceptable (10 %). Globally, a uniform but pale colour was identified by panellists (80%). Smell was described as characteristic (70%) or slightly characteristic (30%). For most panellists (60%), more than 2/3 of the mussels' shell was filled, i.e., meaty, whereas 40% of the panel members described as less meaty, with 2/3 to ½ of the shell filled. Taste was characteristic or mild (50%, each). In general, Spring mussels were defined as slightly soft (50%) and juicy (80%).

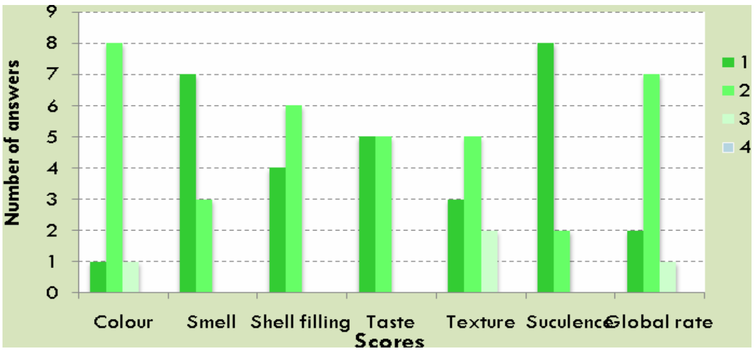

Figure 4. Scores of steamed-cooked mussels harvested in Spring. For each parameter (colour, smell, shell filing, taste, texture, succulence and global rate) the number of answers is evidenced according to the scale classes used (see table 2) represented by the colour coded bars.

2.2. Edible meat content

The average edible meat content of Spring mussels was 59.6 ± 3.8%, which corresponds to 7.5 ± 3.1 g per individual mussel (Figure 6). Spring mussels' meat yields were higher than those obtained by Fuentes *et al.* (2009) in different parts of Spain and in the Scottish spring sample.

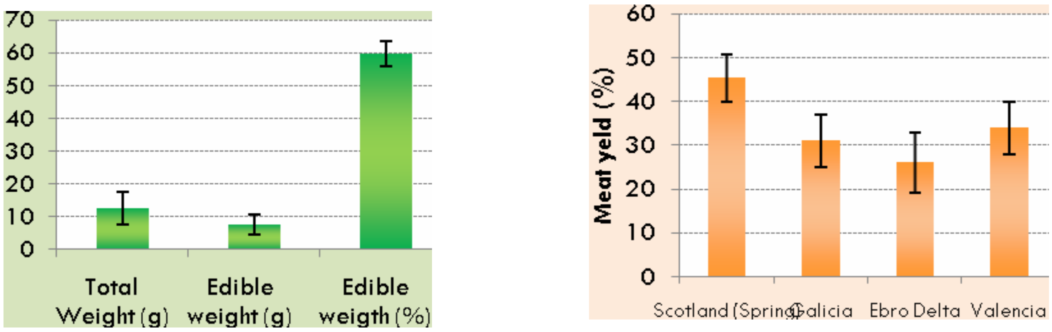

Figure 5. A –Spring mussel's weight including the shell; mussel's edible weight; and proportion of the edible weight to whole animal – meat yield (%). Data is presented as average ± Standard Deviation; B – Meat yield results obtained in mussels harvested in Scotland (Spring - June 2011) and in Spain (July, 2002 data from Fuentes *et al.*, 2009).

2.3. Edible meat coloration

The edible meat coloration was evaluated using three parameters: lightness (L*; 0 means black and 100 means white), red/green (a*; negative values means green and positive values indicate red) and yellow/blue (b*; negative values means blue and positive values indicate yellow). It was found that the meat of Irish mussels harvested in Spring 2011 had whitish colour (L = 44.3 ± 1.9), slightly red (a = 10.3 ± 0.7) and yellowish (b = 18.7 ± 2.4).

In general, steamed cooked mussels were better scored than live mussels due to shell dirtiness. Steam cooked mussel's perceived freshness and quality was scored as good by most panellists. The meat yield was about 60 % and meat coloration was whitish, slightly red and yellowish.

3. CHEMICAL COMPOSITION

3.1. Proximate chemical composition

The proximate chemical composition of Spring mussel samples is shown in Table 3. In general, spring mussels harvested in Ireland had similar chemical composition than those from Scotland (also harvested in Spring) and Spain. However, leaner flesh, lower proteins and higher amounts of carbohydrates (4.3 % ww) were found in Irish mussels.

Proximate Chemical Composition

	Ireland (Spring)	Scotland (Spring)	Galicia	Ebro Delta	Valencia
Moisture	83.3	82.9	79.0	83.8	81.5
Proteins	9.0	9.7	10.0	6.5	10.0
Ash	2.2	2.2	2.2	3.4	3.4
Carbohydrates	4.3	3.8	ND	ND	ND
Fat	1.2	1.5	1.4	1.7	2.2

Table 3. Mussels proximate chemical composition (%). Data is presented as average – Comparison between the composition of mussels from Ireland harvested in Spring and mussels from Scotland (March 2011) and Spain (July, 2002; data from Fuentes *et al*. (2009). ND - No Data.

3.2. Fatty acids

The fatty acid profile (FA) found in Irish mussels harvested Spring 2011 is shown in Figure 7. Saturated fatty acids accounted for 25.8% (SFA) of the total fatty acids and a lower value was obtained for monounsaturated fatty acids, 18.1% (MUFA). Most fatty acids were polyunsaturated (50.6%; PUFA), and belonged to omega-3 family (43.2%; ω3-PUFA).

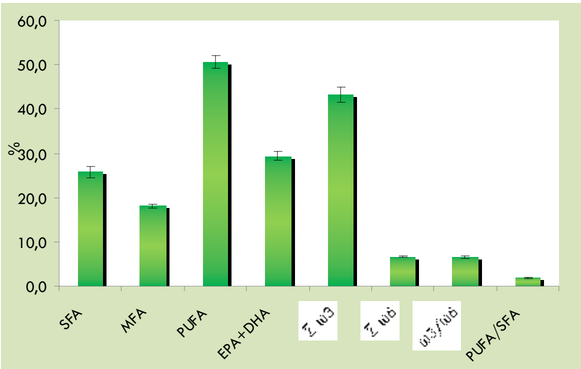

Figure 6. Fatty acid profile (%) of Irish mussels harvested in Spring 2011.

Lipid levels and composition of marine bivalves depend on the biochemical and environmental conditions of seed development, and the ω3/ω6 ratio is an excellent index to compare the relative nutritional value of lipids, where high values generally correspond to better quality foods. Due to the low content of ω6-PUFA, the ω3/ω6 ratios obtained were high (6.5), pointing out an excellent meat quality of the Irish mussels. These values were higher than those found in other bivalve species, such as clams (2.9; Bandarra *et al*., 2004).

In the case of SFA (Fig. 8), palmitic acid (16:0), stearic acid (18:0) and myristic acid (14:0) were the most relevant fatty acids.

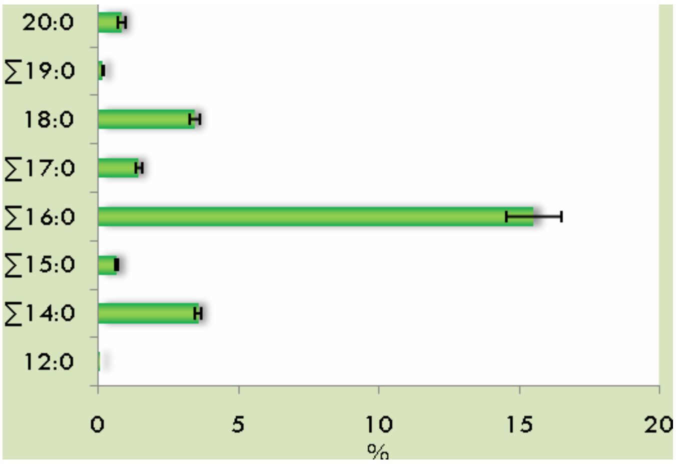

Figure 7. Saturated fatty acid profile in mussels from Ireland harvested in Spring 2011 (%).

Palmitic acid has been reported in numerous studies as the major SFA in mussels (e.g. Alkanani *et al.*, 2007). Concerning MUFA, palmitoleic acid (16:1n-7) was the most abundant fatty acid (see Figure 9).

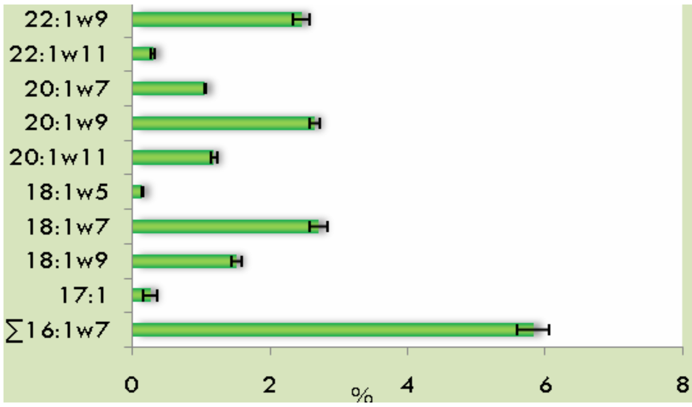

Figure 8. Monounsaturated fatty acids in mussels from Ireland harvested in Spring 2011 (%).

Eicosapentaenoic (20:5n-3) and docosahexaenoic (22:6n-3) acids were the most important PUFA (Figure 10). The intake of ω3-PUFA from natural sources may influence the onset and progression of several human diseases, including cardiovascular diseases and cancer. Ackman (1990) showed the existence of a positive correlation between deaths by coronary illnesses and a high relation of ω6/ω3 (between 12 and 50). In this study, the n-6/n-3 ratio found in all samples was much lower (0.15) than those reported as harmful in literature.

The fatty acid profile is an excellent indicator to assess food fat quality. In this regard, even though mussels' edible meat has an excellent fatty acid profile, the flesh is considered as lean, and, therefore, the contribution in fat is very low. The recommended adequate intake (AI) for ω3 fatty an acid according to the Food and Nutrition Board of the USA (for adult males is 1.6 g/day and 1.1 g/day for adult females).

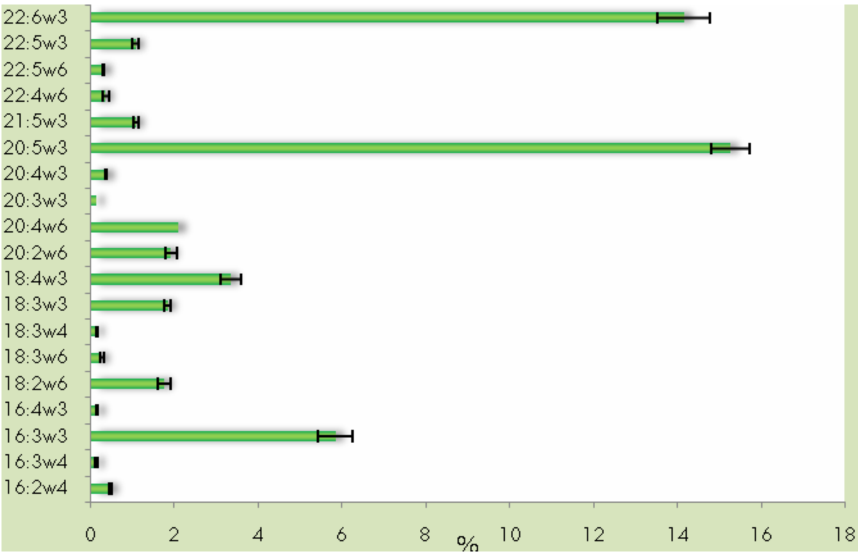

Figure 9. Polyunsaturated Fatty Acids profile in mussels from Ireland harvested in Spring 2011 (%).

3.3. Amino acids

Proteins are composed by more than 20 aminoacids. Yet, only half are considered as essential for human consumption, since they cannot be synthesized by the organism in the cells at a speed commensurate with the demands for normal growth, and consequently, must be provided through the diet. The indispensable amino acids are arginine, leucine, isoleucine, valine, lysine, threonine, tryptophan, methionine, phenylalanine and histidine (FAO/WHO/UNU, 2007). Proteins of Irish mussels harvested in Spring 2011 contained high amounts of non essential amino acids (NEAA), such as aspargine, serine and glutamic acid (Figure 11), while the main essential amino acids (EAA) were arginine, lysine and leucine.

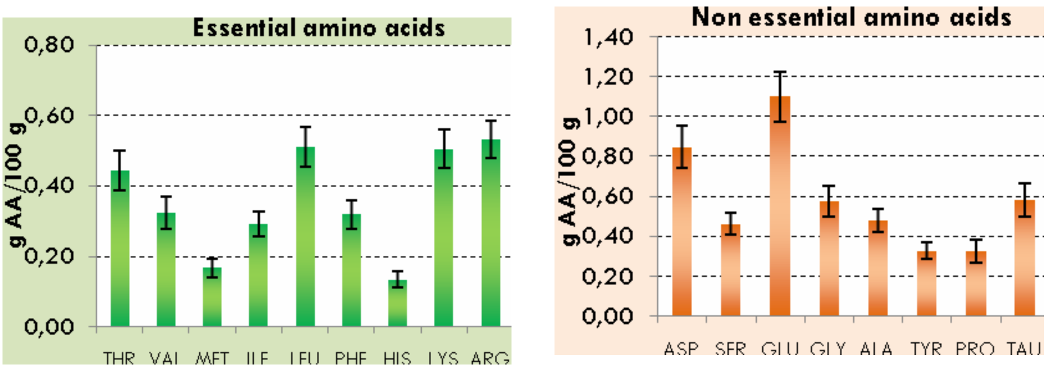

Figure 10. Amino acid profile (g 100 g^{-1} of wet weight) of Winter and Spring mussels. Abbreviations: (THR) threonine; (VAL) valine; (MET) methionine; (ILE) isoleucine; (LEU) leucine; (PHE) phenylalanine; (HIS)

histidine; (LYS) lysine; (ARG) arginine; (ASP) aspartic acid; (SER) serine; (GLU) glutamic acid; (GLY) glycine; (ALA) alanine; (TYR) tyrosine; (PRO) proline; (TAU) taurine.

The contribution of all indispensable amino acids to the total nitrogen content of the food has to be considered in order to assess the overall protein quality of the diet. If the content of a single indispensable amino acid in the diet is less than the individual's requirement, then it will limit the utilization of other amino acids and prevent normal rates of protein synthesis even when the total nitrogen intake level is adequate. Thus, the "limiting amino acid" will determine the nutritional value of the total nitrogen or protein in the diet. The concept of limiting amino acid has led to score amino acids, whereby the indispensable amino acid composition of the specific protein source is compared with that of a reference amino acid composition profile. The amino acid scores in Spring mussels are shown in Figure 12. The highest scores were obtained for threonine and phenylalanine plus tyrosine, scoring over 150% of the adult requirements. Additionally, the nutritional quality of Irish mussels' proteins was evidenced since the S-scores obtained in these samples were close or, in most cases, above 100 %, being three the limiting amino acids, i.e. valine (92 %), leucine (96%) and histidine (98%).

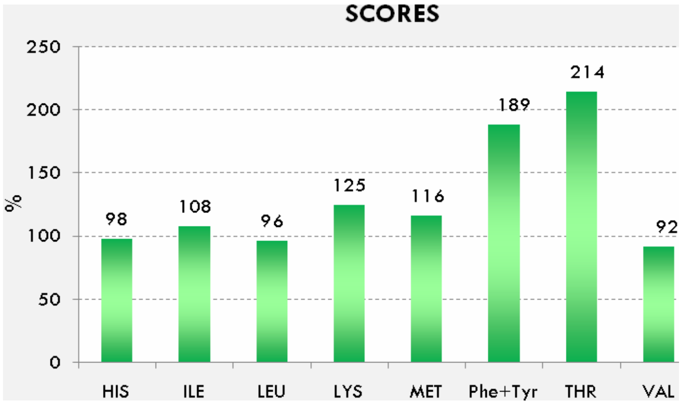

Figure 11. Essential amino acid scores (%) of edible meat of mussels from Ireland harvested in Spring 2011. Abbreviations as in Figure 11.

3.4. Inorganic elements

3.4.1. ESSENTIAL ELEMENTS

Almost all elements considered as essentials, i.e. those provided through the diet and required to maintain normal physiological functions can be found in seafood. Figure 13 shows the elemental composition of mussels from Spring mussels from Ireland.

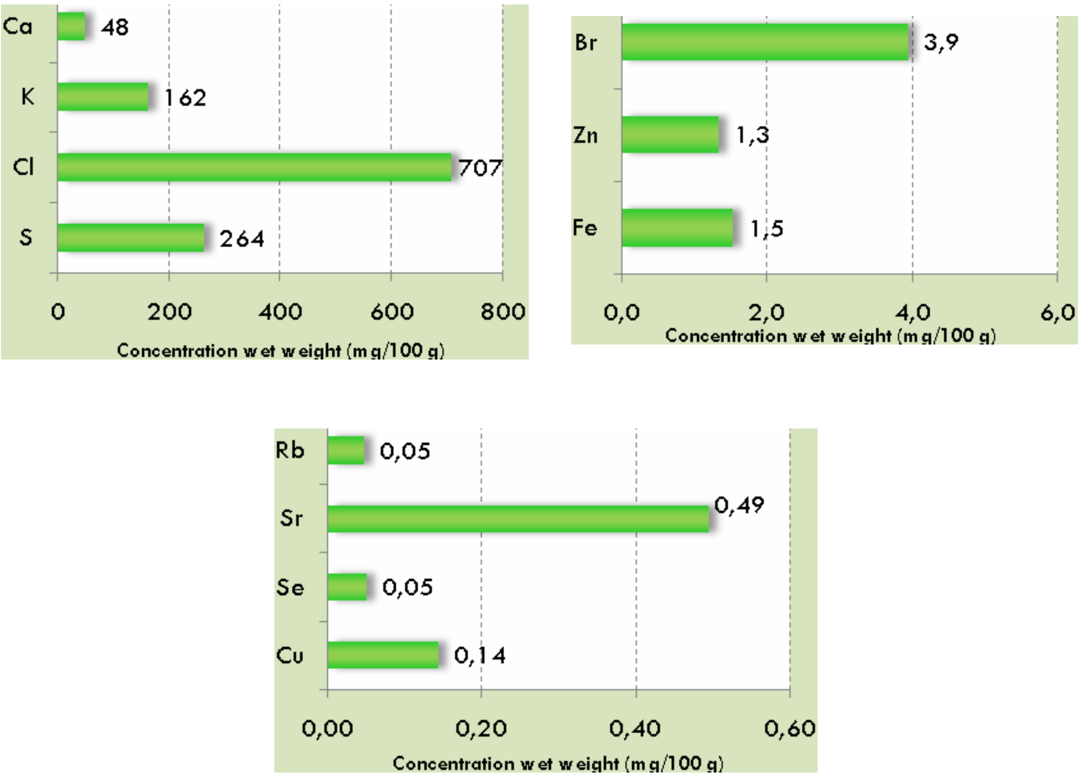

Figure 12. Mean elemental composition in the edible meat of mussels from Ireland harvested in Spring 2011.

Chlorine, S and K were the most representative macro elements, whereas the most relevant trace elements were Br, Zn and Fe. Even though most elements found in seafood are necessary in several human metabolic processes they must be taken from the diet in balanced doses, as low intakes results in nutritional deficiencies, but high intakes can result in toxicity. Considering this dichotomy, risk assessment of essential elements has to take into account the two ends of the toxicity spectrum: that associated with too high intakes (toxicity), and that associated with too low intakes (nutritional deficiencies). The USA Food and Nutrition Board of the Institute of Medicine (IOM) has dealt with nutritional deficiency problems, as well as with their toxicity, by setting dietary reference intakes (DRI), which includes the recommended dietary allowance (RDA), the adequate intake (AI) and the tolerable upper intake level (UL) for essential elements. Table 4 shows the RDA/AI and UL of some essential elements, together with a small description of their functions and adverse effects if consumed in excess. RDA is set to meet the daily dietary needs of almost all (97 to 98 %) healthy individuals in a particular life stage (e.g. infants, children, pregnancy and lactation) and gender group. The AI is believed to cover the needs of all individuals in a life stage group, but lack of data prevent being able to specify with confidence the percentage of individuals covered by this intake. The UL is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population. Considering that an adult may eat the equivalent to 100 g of mussels' edible meat per meal (approximately, 13 mussels), this product is an excellent source of Se and a good source of Cu, Fe and Zn for consumers.

Table 4. Dietary reference intakes for essential elements (mg/day) from food and water (adapted from Barrento, 2010).

Element	Function	RDA/AI	UL	Adverse effects of excessive consumption
Potassium K	Required for normal cellular function	4700*	ND	Hyperkalemia
Calcium Ca	Blood clotting, muscle contraction, nerve transmission, bone and tooth formation	1000*	2500	Kidney stones, hypercalcemia, milk alkali syndrome and renal insufficiency
Iron Fe	Prevents anemia	**18** (♀) **8** (♂)	45	Gastrointestinal distress
Copper Cu	Component of enzymes in iron metabolism	**0.9**	10	Gastrointestinal distress, liver damage
Zinc Zn	Component of multiple enzymes and proteins, involved in the regulation of gene expression	**8** (♀) **11** (♂)	40	Reduced Cu levels
Selenium Se	Protection against oxidative stress, regulation of thyroid hormone action, reduction and oxidation of vitamin C and other molecules	**0.055**	0.4	Hair and nails brittleness and loss

Abbreviation: (RDA) recommended dietary allowance; (AI) adequate intake; (UL) tolerable upper intake levels. RDA values are in bold type while AI are in ordinary type followed by an asterisk (*). All reference intakes shown are for adult males (♂) and females (♀) aged 19 to 50 years. (ND) not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts. Source of intake should be from food only to prevent high levels of intake (IOM, 1997; 2001; 2004); (†) female and male adults aged between 31 and 50 years.

3.4.2. CONTAMINANTS

In addition to essential elements, toxic elements such as Hg, Cd, Pb and As can also be found in some marine species. Such elements are available in water from natural sources, such as rocks, and as a result of human activities like emissions from industrial processes. These elements are taken up by marine organisms through the diet and gills and tend to accumulate in species from higher trophic levels like fish and shellfish (EFSA, 2004, 2005). Regular consumption of contaminated seafood can cause poisoning and promote diseases. In the European Union, the European Commission has set maximum levels for Cd, Pb and Hg, but not for As (EC No. 1881/2006; Table 5). To ensure an efficient protection of public health, products containing contaminants exceeding the maximum levels should not be placed on the market either as such, after mixture with other foodstuffs or used as an ingredient in other foods (EC No. 1881/2006).

The results shown in Figure 14 indicate that mussels harvested in Spring 2011 in Ireland are safe for consumption, as very low concentrations were found and always below the ML.

Table 5. Maximum level (ML, ppm) for Hg, Cd and Pb in bivalves according to the EC regulation No 1881/2006 of 19 December 2006, setting maximum levels for certain contaminants in foodstuffs.

Element	ML (ppm)	Adverse Effects	Observations
Arsenium As	ND	No data on the possible adverse effects of organic arsenic compounds in food were found. Inorganic arsenic is a known toxic substance.	There is no established maximum level for Arsenic yet.
Cadmium Cd	1.0	Nephrotoxicity, osteoporosis, carcinogenicity and genotoxicity, teratogenicity, and endocrine and reproductive effects.	Long biological half-life in mammals. In humans, steady-state concentrations in the renal cortex are reached after about 40 years.
Lead Pb	1.5	Neurotoxicity, anaemia, renal toxicity and subsequent carcinogenicity and cardiovascular effects; impairment of the reproductive system.	Pb in seafood is inorganic, and is bound to proteins. Bioaccumulation in marine animals is low compared to mercury. Main sites of Pb accumulation in seafood: internal organs, skin and bone, but not in muscle.
Mercury Hg	0.5	Neurotoxicity. High exposure in uterus has resulted in cerebral palsy or severe mental retardation in the neonate.	Organic Hg is considered to be more toxic than other forms of Hg following ingestion. Methyl-Hg is the predominant form of Hg in fish (> 90 %).

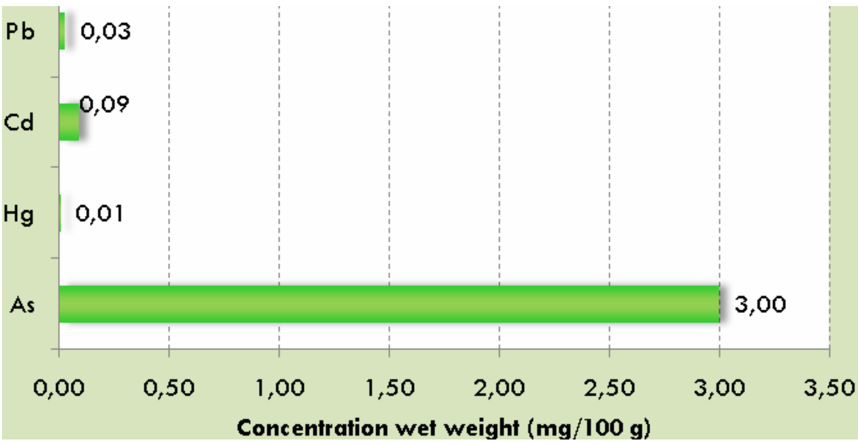

Figure 134. Mean toxic element composition in the edible meat of mussels from Ireland harvested in Spring 2011.

Overall Irish mussels harvested in Spring are lean, with a high quality protein and fat contents, an excellent source of selenium and a good source of Cu, Fe and Zn. Additionally, mussels harvested in Ireland are safe for consumption as far as toxic elements are concerned.

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