The Mussel *Mytilus Galloprovincialis*: Nutritional Quality and Bioindicator of Availability of Radionuclides in the Marine Environment (Algerian Basin)

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Abstract A study was undertaken to determine the level of biochemical contents and the activity concentrations of the radionuclides in Algerian mussels (*Mytilus galloprovincialis*). The determination of biochemical contents (lipids, carbohydrates, and proteins) allowed us to evaluate the benefits of mussel consumption. The mussels used at the same time as bioindicator of naturally occurring radionuclides (^{210}Pb, ^{214}Pb, ^{226}Ra, ^{214}Bi), telluric (^{40}K), and artificial radionuclides (^{137}Cs) from seawater. The biochemical contents were measured by (UV–Visible) Colorimetric assays, and the activity concentrations of radionuclides were measured by gamma spectrometry. The mussels were taken from three study areas on the Algerian coast: Kristel (Oran), Sercouf (Alger), and Collo (Skikda); and transplanted from each study areas into the tampon site (common site of Sercouf). The choice of sexual dormancy period and tampon site was a means of minimizing the effect of biological and environmental conditions on the bioaccumulation of radionuclides by mussels. The results show that the carbohydrates were the most abundant biochemical components (40–60%) compared to proteins (20–40%), and lipids (15–20%) of the total composition of the mussels. Not all treated mussels were contaminated with ^{137}Cs, the high activity of

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^{40}K was the result of its high availability in the marine environment and its bioaccumulation in the mussel flesh. However, low ^{226}Ra activity was measured compared to ^{40}K, while ^{210P}b activity was measured between ^{40}K and ^{226}Ra. The Kristel site was the most impacted area.

Keywords Proximate composition · Radioactivity · Biomonitoring · Mussel transplanted · Southwestern mediterranean

1 Introduction

The genus *Mytilus* has been used as a sentinel organism for pollution [1]. Mussels are generally appreciated for their nutritive quality; they are an important dietary source of proteins, carbohydrates, and minerals, with beneficial roles in human health. The radionuclides in the marine environment can pass along the food chain and be transferred to humans [2]. Most of the radiation exposure of humans comes from naturally occurring radionuclides (^{238}U and ^{232}Th series radionuclides plus ^{40}K). The ^{137}Cs is the most important artificial radionuclide, in regard to radioecology research and its accumulation mostly in soft tissue [3]. Radionuclides can cause harmful effects, including human infertility, and carcinogenic effects [4].

2 Materials and Methods

The sampling study areas were (S1) Kristel, Oran (35,812,550° N/0,499,917° W), (S2): Sercouf, Algiers (36,794,371° N/3,316,147° E), and (S3): Collo, Skikda (36,998,665° N/6,573,177° E). Each sampling consists of the collection of 150–300 mussels (corresponding to a wet wt of 3 kg) [5]. Another 3 kg of mussels (from each study area) were transplanted into the tampon site (common site of Sercouf), from the end of April to the beginning of August 2017. The immersion process was carried out during the mussels' sexual dormancy period. The mussel soft tissues were removed and pooled, then, freeze-dried. Dry soft tissues were homogenized prior to analyses. The total lipid determination was performed using the Folch method [6] modified by Christie [7]. The carbohydrates were dosed according to Dubois et al. [8]. The determination of protein was described by Lowry et al. [9]. The natural radioisotope in the soft mussel was carried out using gamma spectrometry technique without any specific pretreatment [10].

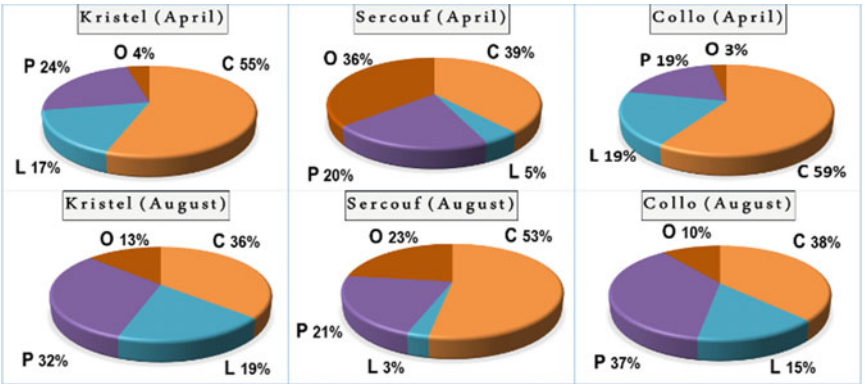

Fig. 1 Lipid (**L**), Carbohydrate (**C**), and Protein (**P**) content in mussels *M. galloprovincialis* during sampling and after transplantation. (**O**): other contents

3 Results

3.1 Nutritional Quality

Mussels collected at Kristel were rich in protein (23.56%). However, the highest content of carbohydrate (58.92%) and lipid (19.52%) determined in the mussels collected from Collo. After transplantation in Sercouf site, individuals collected from Collo were characterized by the highest protein content (36%) and those collected from Kristel showed the highest percentage of lipids (18.94%). On the other hand, native mussels (originating from S2) have the highest carbohydrate content (52.89%) (Fig. 1).

3.2 Radioactivity Biomonitoring

During sampling, the highest activities of ^{40}K (256.60 ± 7.93 Bq kg^{-1} dw), ^{226}Ra (7.62 ± 0.22 Bq kg^{-1} dw), and ^{210}Pb (256.60 ± 7.93 Bq kg^{-1} dw) were determined in mussels taken from Kristel. After transplantation, the highest activity of ^{40}K (264.70 ± 7.70 Bq kg^{-1} dw) was found in mussels collected from Collo. However, the most important activities of ^{226}Ra (3.10 ± 0.14 Bq kg^{-1} dw) and ^{210}Pb (26.86 ± 2.43 Bq kg^{-1} dw) were observed in mussels coming respectively from Sercouf and Kristel (Table 1).

Table 1 Activity concentrations of radionuclides in soft tissues of mussel samples *M. galloprovincialis* (Bq kg^{-1} dw) during sampling (April) and after transplantation (August)

Radionuclides	Period	(S1) Kristel (Oran)	(S2) Sercouf (Alger)	(S3) Collo (Skikda)
Cs (137)	April, 2017	<0.01	<0.01	<0.01
	August, 2017	<0.01	<0.01	<0.01
K (40)	April, 2017	256.60 ± 7.93	244.75 ± 7.25	201.66 ± 6.24
	August, 2017	242.43 ± 7.52	192.16 ± 5.82	264.70 ± 7.70
Ra (226)	April, 2017	7.62 ± 0.22	3.74 ± 0.14	4.31 ± 0.17
	August, 2017	2.14 ± 0.16	3.10 ± 0.14	2.65 ± 0.15
Bi (214)	April, 2017	7.65 ± 0.45	3.95 ± 0.29	4.68 ± 0.36
	August, 2017	2.10 ± 0.31	3.82 ± 0.29	2.91 ± 0.31
Pb (214)	April, 2017	7.58 ± 0.41	3.53 ± 0.29	3.94 ± 0.33
	August, 2017	2.19 ± 0.31	2.37 ± 0.26	2.39 ± 0.28
Pb (210)	April, 2017	18.93 ± 1.73	18.71 ± 1.79	10.45 ± 1.08
	August, 2017	26.86 ± 2.43	15.92 ± 1.46	21.68 ± 1.85

4 Discussion

Carbohydrate is the most abundant biochemical component in the studied mussels. Its percentage varied between 40 and 60% of the total composition; the highest contents are recorded in mussels collected from Kristel and Collo. These readings (%) are highest compared to those quoted in the bibliography [11–14]. Proteins varied between 20 and 40% of the biochemical component. The content of proteins in the mussels' soft tissue is high compared to the results from previous studies [11–16]. Lipids vary in a narrow range [15–20]% in the mussels collected from Kristel and Collo; these levels are close to those reported by Irisarri et al. [13]. The lipid content in Sercouf mussels does not exceed 5%, this content is close to that reported in [11, 12, 14, 15]. During sampling and after transplantation, the variation of biochemical component shows a similar tendency in the mussel collected from Kristel and Collo ($p < 0.05$; Fig. 1).

The high activity concentrations of ^{40}K in mussels' tissue are due to the bioaccumulation of this radionuclide from seawater. The concentration of ^{40}K in the seas and oceans is high and uniform (~12,500 Bq m^{-3}) and consequently does not change in coastal seawaters even if stronger terrigenous effects take place [17, 18]. It can be concluded that the variation of ^{40}K concentration between sites and after transplantation is a reflection of the conditional state of mussels. In fact, this biogenic element ^{40}K is extensively used in the metabolism of the organisms [17]. The ^{226}Ra activity concentration is the average activity concentration of ^{214}Pb and ^{214}Bi [19]. In fact, the activity concentrations of ^{214}Pb and ^{214}Bi undergoe the same spatiotemporal variation as the activity concentration of ^{226}Ra. The activity concentration of ^{226}Ra is low (factor of 30) compared to ^{40}K's activity concentration, because the natural radionuclide ^{226}Ra can not be accumulated in soft tissues [17]. It is important to

measure the activity of ^{210}Pb, as this radionuclide is a continuous source of ^{210}Po [20]. The ^{40}K, ^{226}Ra, and ^{210}Pb activities measured in *M. galloprovincialis* mussels are in the same range as reported in other parts of the world [3, 10, 17].

5 Conclusion

All the analyzed mussels are rich in carbohydrates, proteins, and lipids. The measured activity concentrations of anthropogenic ^{137}Cs in mussels' dry tissue were below the detection limits. The ^{226}Ra is not bioaccumulated by mussels, explaining thus its weak activity. The important activity of ^{40}K is related to its substantial availability in marine environment and its bioaccumulation. According to our results, the environment does not affect the nutritional quality and the accumulation capacity of radionuclides by mussels.

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