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Fatty acids in the circulatory system of an invasive king crab from the Barents Sea

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Highlights

- PUFA dominated in the cardiac muscle (59.7%) and hemolymph (42.8%).
- Fatty acid levels were similar in males and females and in different-sized crabs.
- Total FA in hemolymph on soft bottoms were higher than on hard bottoms.
- Cardiac muscle contained 1.5–3 times higher FA concentrations than leg muscle.
- Optimal dietary n-3/n-6 ratios were found in both cardiac muscle and hemolymph.

Abstract

We assayed fatty acids in the cardiac muscle and hemolymph of adult crabs collected in the coastal Barents Sea. Polyunsaturated fatty acids were the major fatty acids (273 $\mu g mL^{-1}$ or 42.8% in the hemolymph and 3130 $\mu g g^{-1}$ or 59.7% in the cardiac muscle) followed by saturated fatty acids (201 $\mu g mL^{-1}$ or 33.9% and 1290 $\mu g g^{-1}$ or 24.8%, respectively) and monounsaturated fatty acids (143 $\mu g mL^{-1}$ or 23.3% and 815 $\mu g g^{-1}$ or 15.6%, respectively). The n-3/n-6 ratios in these tissues were 3.4 and 4.3, respectively. Fatty acid profiles were similar in females and males, in crabs with different shell conditions and in different-sized crabs. The crabs captured on soft bottoms contained significantly higher concentrations of fatty acids in their hemolymph than the crabs from hard bottoms probably owing to differences in their diets. In general, fatty acid levels in the cardiac muscle were 1.5–3 times higher than in the leg muscle reflecting higher functional load of the heart compared to walking legs. We suggest that both byproducts that now are discarded during red king crab processing could be considered additional sources for extracting valuable n-3 fatty acids.

Introduction

The red king crab, *Paralithodes camtschaticus* (Tilesius, 1815) being a large commercially important crustacean was intentionally introduced into the Barents Sea in the 1960s by Russian scientists to establish a resource for the local fishery (Dvoretsky and Dvoretsky, 2015a). This species has adapted successfully and formed a self-sustaining population (Dvoretsky and Dvoretsky, 2014a, Dvoretsky and Dvoretsky, 2015a). In Russian waters of the Barents Sea, commercial fishing for *P. camtschaticus* was opened in 2004 (Dvoretsky and Dvoretsky, 2018).

Over the last two decades, the red king crab in the Barents Sea has been intensively studied and new data were obtained for population dynamics and distribution patterns (Dvoretsky and Dvoretsky, 2013a, Dvoretsky and Dvoretsky, 2016, Dvoretsky and Dvoretsky, 2022a, Matishov et al., 2012, Spiridonov et al., 2020, Strelkova et al., 2021), reproduction and growth (Dvoretsky and Dvoretsky, 2012, Dvoretsky and Dvoretsky, 2013a, Dvoretsky and Dvoretsky, 2014b, Dvoretsky and Dvoretsky, 2015b), feeding and behavior (Sundet and Berenboim, 2008, Pavlova, 2015), symbiotic relationships (Dvoretsky and Dvoretsky, 2011, Dvoretsky and Dvoretsky, 2013a, Dvoretsky and Dvoretsky, 2013b, Dvoretsky and Dvoretsky, 2021a, Dvoretsky and Dvoretsky, 2022b), and fishery aspects (Dvoretsky and Dvoretsky, 2015a, Dvoretsky and Dvoretsky, 2018, Dvoretsky and Dvoretsky, 2022a). Although recent studies have provided information on the fatty acid composition of some red king crab tissues and organs such as hepatopancreas and leg muscles (Dvoretsky et al., 2020,

Dvoretsky et al., 2021a, Lian et al., 2022), biochemical investigations of the red king crab circulatory system are still nascent not only in the Barents Sea but also in the native area of this crustacean. There is no distinction between interstitial fluids and blood within crabs, therefore, they possess a semi-closed or semi-open circulatory system. According to Donaldson, Byersdorfer (2014), (p. 77–78), "the circulatory system of *P. camtschaticus* is composed of the heart, arteries, and pericardial cavity. Venous blood flows through the spaces (the hemocoel) between the various organs. In the gills, carbon dioxide, which has been picked up from the body tissues, is exchanged for oxygen via a countercurrent mechanism. The branchial sinus leads the venous blood through the branchial lamellae, where it becomes oxygenated and returns via the branchial artery. The arterial blood then passes from the branchial vein into the pericardial sinus and flows out of the heart". Hemolymph is known to primarily circulate within the crab body cavity as a result of muscle contractions (McMahon and Burnett, 1990). The hemolymph of red king crabs is the largest tissue in these animals by volume and consists of water, inorganic salts, organic compounds, and hemocytes (Morado et al., 2014). In the Barents Sea, hemolymph studies are limited to hemocyanin screenings in relation to the meat content of red king crabs (Moiseeva and Moiseev, 2008), research of thyroid hormones in relation to size and sex (Dvoretsky et al., 2022c), assays of circulating ecdysteroids in relation to molting status (Dvoretsky and Dvoretsky, 2010), assessment of free amino acids in relation to stress (Mota et al., 2021), and studies of seasonal variations in levels of vertebrate-like sex hormones in relation to sex and size (Dvoretsky et al., 2021b). Also, there are no data regarding fatty acid profiles in the cardiac muscle of red king crab.

Recent red king crab stock assessments have shown an increase in both the total number of crabs and annual landings in the Barents Sea (Dvoretsky and Dvoretsky, 2018). For example, the total annual catches reached a level of 10,000t (Dvoretsky and Dvoretsky, 2021b). The yield of red king crab meat is 22–24%. From the other crab remnants, only hepatopancreas and carapaces are used for extracting chitin, chitosan, some proteolytic enzymes including collagenases, and other products (Novikov et al., 2020, Ponomareva et al., 2021). Rough estimates show that at least 350–550t of hemolymph is lost and wasted every year. This is owing to some difficulties in hemolymph processing and absence of the data on its fatty acid profiles. Cardiac muscles are also not used in the food and pharmaceutical industries due to their relatively small sizes. Moreover, both hemolymph and cardiac muscles are not considered food sources and are not treated as the edible part of red king crab.

Thus, the aim of this study was to measure concentrations of fatty acids in hemolymph and the cardiac muscle of the Barents Sea red king crabs and to test the hypothesis whether the fatty acid profiles differ in relation to the crab sex, size, shell conditions, limb injury status

and benthic habitats, and to compare fatty acid profile among hemolymph and cardiac muscles of *P. camtschaticus*.

Section snippets

Collection procedures and crabs

Red king crabs (n=95) were collected by divers (depth range 5–30 m) during coastal expeditions in Dalnezelenetskaya Bay, a small gulf (total area 2.23 km^2) of the Eastern Murman of the Barents Sea (69°07.5′N, 36°06.0′E). There are 5 islands in the area. They separate the bay from the open sea. Temperature minimum and maximum occur in February (0.7 °C) and August (9.7 °C) although in some years the maximum could be registered in July (Dvoretsky and Dvoretsky, 2020a, Dvoretsky and Dvoretsky,…

Results

The sex ratio during our surveys showed a greater proportion of females than males with the ratio being 3:1 in 2015 ($df = 1$, $\chi^2 = 12.000$, $p = 0.001$), 6.8:1 in 2016 ($df = 1$, $\chi^2 = 16.948$, $p < 0.001$) and 4.3:1 for the combined data ($df = 1$, $\chi^2 = 23.182$, $p < 0.001$). Size variation in the red king crabs collected for the hemolymph sampling is presented in Table 2. In Dalnezelenetskaya Bay, mean carapace length in males was significantly higher than in females ($df = 1$, $H = 16.948$, $p < 0.001$). The…

Discussion

Being a diverse group of molecules that are found in and constitute the major components of oils (triacylglycerols), fats, waxes, and other lipid-containing materials, fatty acids are important chemical feedstocks (Metzger, 2009). They provide a high calorie foodstuff in many metabolic processes, the structural basis of biological membranes, and an important class of extra- and intracellular signaling molecules (Geiger, 2016). In crustaceans, the importance of fatty acids increases considerably …

Conclusion

Two main components of the red king crab circulatory system, the cardiac muscle and hemolymph, were assayed to reveal their fatty acid composition for the first time, thus our study expands the knowledge on the biochemical composition of this commercially important species. Like in tissues of many other crustaceans, n-3 PUFA dominated fatty acid profiles followed by SFA and MUFA. Crab sex, size, shell condition and number of injured limbs did not affect fatty acid concentrations in *P.*...

CRediT authorship contribution statement

Alexander G. Dvoretsky: Conceptualization, Investigation, Writing – original draft, Project administration. **Fatima A. Bichkaeva**: Validation, Methodology, Investigation, Formal analysis, Writing – review & editing. **Nina F. Baranova**: Validation, Methodology, Formal analysis, Writing – review & editing. **Vladimir G. Dvoretsky**: Data curation, Investigation, Visualization, Writing – original draft...

Declaration of interests

The authors of the paper **"Fatty acids in the circulatory system of an invasive king crab from the Barents Sea"** declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper...

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Conflict of interest

The authors declare no conflict of interest...

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