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Energy value and chemical composition (CHN) of the Chinese mitten crab *Eriocheir sinensis* (Decapoda: Grapsidae) from the Baltic Sea

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Abstract

The present study was undertaken to determine the energy value and chemical composition of the Chinese mitten crab *Eriocheir sinensis* Milne-Edwards, 1854, which is one of a few newcomers to the Baltic Sea. The average energy value of the studied specimens of *E. sinensis* was $10.96 \pm 2.11\,\mathrm{J\,mg^{-1}}$ DW ($15.30 \pm 2.42\,\mathrm{J\,mg^{-1}}$ AFDW). Carbon was the major constituent of *E. sinensis* ($33.2 \pm 3.5\%$ DW), whereas the nitrogen and hydrogen content was 6.3 ± 0.5 and $4.7 \pm 0.5\%$ DW, respectively. The organic C:N ratio in *E. sinensis* was 4.8 ± 0.6, on average.

Keywords: Eriocheir sinensis; Chemical composition; Energy value; The Baltic Sea

1. Introduction

Studies of the energy value of animals are an important element of bioenergetics. They can be used to determine the suitability of animals as food sources, as well as to balance energy budgets, which, along with population data, paint a picture of the functioning of the trophic chain [1]. Also application of the same units, i.e. joules or calories per mass unit facilitates the comparison of materials of different origins.

To date, investigations of the energy value of organisms from the Gulf of Gdansk have encompassed both the flora [2] and fauna [3–8]. Over the past several years, however, new species have appeared in the Gulf of Gdansk. One of them is the crab *Eriocheir sinensis* whose original habitat was the China Sea. This is the largest crustacean species inhabiting Polish waters. It is catadromous species that spends most of its life in fresh waters and only migrates to the sea to reproduce [9]. Since the beginning of the 1990s, large individuals of this crab have become more and more common in the Polish coastal zone, where they are caught in fishing nets [10]. The presence of this alien species is not without significance in the food chain. Its food consists mostly of algae, worms, mussels, snails, inferior crustaceans and water insects; *E. sinensis* is also prey for wading birds, fishes and seals. These crabs are also a potential source of food for humans, and a recent study revealed that *E. sinensis* is being consumed more often [11]. The price per kg of this crustacean in Asian markets is about US$ 30.

It is for the above reasons, that the present study to determine the energy value and the chemical

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composition of *E. sinensis* from the Gulf of Gdansk was undertaken.

2. Experimental

The specimens for analyses were collected with eel traps in the Gulf of Gdansk in the summer months of 1998 and 1999. After collection, the animals were frozen at a temperature of $-30\,^{\circ}$C and preserved for further analyses. After defrosting, the length and width of the crabs' carapaces were measured using a slide caliper (± 0.1 mm), their sex was determined from the structure of their abdomen [12] and they were weighed wet on an electronic PRECISA 125A automatic scale (± 0.001 g). The specimens were then dried at a temperature of $55\,^{\circ}$C in order to obtain their constant, or dry, weight. After weighing the whole dried animals, they were ground in a mortar and homogenized in a vibrating powder mill. Next, a small portion of the sample (<60 mg) was formed into a pellet. The energy values of the *E. sinensis* specimens were determined using a modified Phillipson KMB-2 type microbomb calorimeter described in Klekowski and Beczkowski [13], and Prus [14], and the bomb was calibrated using benzoic acid samples with a known caloric content. Three replicates were performed for each crab sample. The energy values are expressed as joules per milligram of dry weight (J mg^{-1} DW) and per milligram of ash-free dry weight (J mg^{-1} AFDW).

Carbon (C), hydrogen (H) and nitrogen (N) contents were determined with a Perkin-Elmer PE CHNS/O 2400 Series Elemental Analyzer following the procedure in Gnaiger and Bitterlich [15]. The organic fractions were determined after ashing at $450\,^{\circ}$C for 12 h as the mass loss before and after burning. Carbon, hydrogen and nitrogen contents as well as organic matter content were expressed as a percentage of dry weight (DW, %).

Linear regression ($y = ax + b$, where a is the intercept and b is the allometric coefficient) and correlation coefficient (R) were used to determine the relationship between the energy value and chemical composition. The criterion for significance was $p < 0.05$.

3. Results

The energy value of *E. sinensis* varied between 6.57 and 14.85 J mg^{-1} DW and was, on average, 10.96 ± 2.11 J mg^{-1} DW. The energy value of organic matter ranged from 10.50 to 19.36 J mg^{-1} AFDW; on

Table 1
Total (tot) and inorganic (ash) carbon, hydrogen and nitrogen content in *E. sinensis*

Sample	Carapace width (mm)	C tot (%)	H tot (%)	N tot (%)	C ash (%)	H ash (%)	N ash (%)	Organic matter (DW, %)
1	54.0	30.49	4.21	5.75	9.22	0.07	0.13	56.87
2	50.4	32.93	4.77	5.80	8.25	0.09	0.10	60.27
3	56.4	31.11	4.76	6.26	8.75	0.16	0.18	58.35
4	59.6	30.01	4.11	6.00	9.05	0.08	0.11	58.26
5	54.0	29.97	4.68	5.75	9.51	0.11	0.19	56.73
6	42.5	29.72	4.49	6.07	8.71	0.10	0.23	56.96
7	43.0	30.85	4.42	6.25	8.40	0.15	0.14	59.45
8	53.5	36.04	4.85	7.09	9.80	0.08	0.10	63.00
9	55.0	34.35	4.69	6.33	9.71	0.06	0.09	61.14
10	50.0	38.60	5.38	7.20	9.27	0.08	0.10	67.38
11	54.0	35.64	4.92	5.64	9.52	0.08	0.08	63.44
12	53.4	27.21	3.64	6.31	9.26	0.09	0.09	51.41
13	51.5	33.88	4.69	6.49	9.53	0.04	0.08	61.33
14	69.0	31.08	4.49	5.98	9.92	0.07	0.13	53.54
15	48.5	38.22	5.58	6.09	9.63	0.05	0.20	65.09
16	52.6	38.05	5.52	6.10	9.34	0.07	0.27	63.74
17	50.4	36.86	5.36	7.43	9.46	0.04	0.09	64.77
Average	52.81	33.24	4.74	6.27	9.25	0.08	0.14	60.10
±S.D.	5.99	3.51	0.52	0.52	0.47	0.03	0.06	4.27

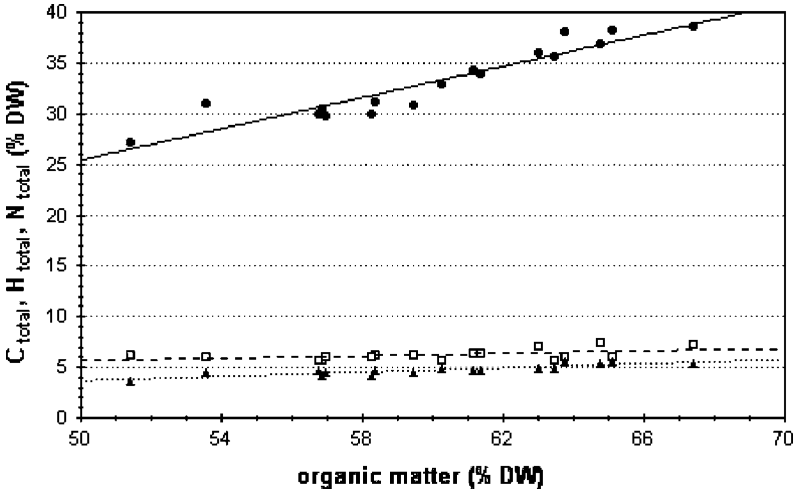

Fig. 1. Relationship between carbon (●, $y = 0.77x - 13.03$, $R = 0.94$), hydrogen (▲, $y = 2.71 + 0.06x$, $R = 0.87$) and nitrogen (□, $y = 0.10x - 1.57$, $R = 0.49$) contents and organic matter in *E. sinensis*.

average, it was $15.30 \pm 2.42\,\mathrm{J\,mg^{-1}}$ AFDW. The organic matter changed in *E. sinensis* from 51.4 to 65.1% DW (with an average of 60.1 ± 4.3% DW). A significant correlation ($p < 0.05$, $R = 0.71$) between energy value and organic matter content was noted. The C content varied between 27.2 and 38.6% DW and was, on average, 33.2 ± 3.5% DW, whereas the nitrogen content was between 5.6 and 7.4% DW, or on average, 6.3 ± 0.5% DW (Table 1). The hydrogen content was the lowest, between 3.6 and 5.9% DW; on average it was 4.7 ± 0.5% DW. Carbon ($R = 0.94$), followed by hydrogen ($R = 0.87$) and nitrogen ($R = 0.49$), was significantly ($p < 0.05$) correlated to total organic matter content (Fig. 1). The energy value of *E. sinensis* was significantly ($p < 0.05$) correlated to C content ($R = 0.78$) and to H content ($R = 0.72$) (Fig. 2).

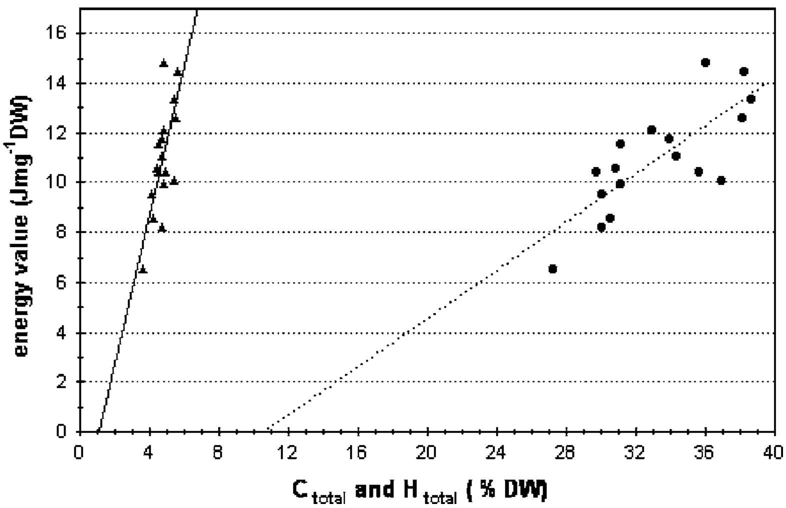

Fig. 2. Relationship between energy value and carbon (●, $y = 0.48x - 5.12$, $R = 0.78$) and hydrogen (▲, $y = 2.99x - 3.24$, $R = 0.72$) contents in *E. sinensis*.

Table 2
Organic matter content and energy value (average ± S.D.) of crustaceans living in the Baltic Sea

Species	Organic matter (DW, %)	Energy value ($J\,mg^{-1}$ DW)		Reference
Idotea sp.	–	12.38 ± 1.14	14.91 ± 2.18	[16]
Saduria entomon	72.4	10.85 ± 2.82	14.97 ± 1.25	[28]
Pontoporeia affinis	–	18.06 ± 1.22	21.02 ± 2.12	[16]
Corophium volutator	68.4	12.69 ± 3.49	18.22 ± 2.49	[6]
Mysis mixta	–	24.75 ± 2.47	27.05 ± 2.46	[16]
Neomysis integer	87.4	18.83 ± 1.11	21.25 ± 1.27	[29]
Crangon crangon	85.1	16.98 ± 1.78	20.06 ± 2.34	[3]
Palemon adspersus	84.0	19.81 ± 1.79	22.52 ± 1.75	[30]
Rhithropanopeus harrisii tridentatus	62.3	7.97 ± 1.50	12.69 ± 2.10	[8]
E. sinensis	60.1	10.96 ± 2.11	15.30 ± 2.42	This study

4. Discussion

E. sinensis has one of the lowest energy values of all Baltic crustaceans (Table 2). Only the mud crab *Rhitropanopeus harrisii tridentatus* has a lower energy value at a lower organic matter content [8]. According to Prus [1], when comparing the energy values of different species or species groups, it is preferable to consider the organic matter energy value, as the stored energy amounts are compared and not the ash amounts. It must be kept in mind, though, that only large, thus the oldest, *E. sinensis* individuals were used in the present study, and that the size and age of the individuals are a significant factors which influence both the organism's energy value [16] and chemical composition [17]. The energy value also depends on organism life strategy [18]. On the other hand, high energy values occur in organisms which are preparing for significant energy output, e.g. that which is expended during reproduction [1]. *E. sinensis* reproduces only once, at the end of its life. Reproduction occurs in saline waters where crabs migrate in late spring. The individuals used in this study were probably migrating to reproduce. Thus, it could be expected that they stored significant amounts of energy. Additionally, organisms may collect lipids in the late stages of their lives; however, this is dependent on the surrounding environment [19]. But the obtained results have not confirmed these hypothesis. Benthic species, represented mainly by *Anomura* and *Brachyura*, have lower energy values in comparison with typical nektobenthic species (Table 2). Moreover, the energy value of predators is higher than that of detritophages [1]. The results of a study on the diet of the Chinese mitten crab revealed that flora constituted 41% of its diet, while detritus was 32%. The energy value of *E. sinensis* is significantly correlated ($p < 0.05$) with the organic matter contents. The correlation coefficient R^2 equal to 0.5 is lower than that reported by Wacasey et al. [20] for benthic invertebrates from the Arctic. It is known though, that the correlation coefficient does not only depend on the place of origin of a species, but also on the analysis technique applied [20]. The energy value of *E. sinensis* is significantly dependent on carbon content; however, the regression coefficient is much lower in comparison to values obtained by Salonen et al. [21] for other aquatic invertebrates.

C, N and H are the predominant organically bound elements. Chemical composition can be influenced by various factors including developmental stage, temperature, salinity, food availability and nutritional conditions [22,23]. The average contents of carbon, nitrogen, and hydrogen in Decapoda larvae is >35, 8–11 and 5–6% DW, respectively [22]. The values of C and H obtained for mature *E. sinensis* are comparable with these data. In addition to the protein N, younger individuals may also have mucoproteins, which are assimilated and used in the processes of tissue building [24]. It is known that the C, N and H contents vary as organism mass increases. This may be caused by changes in the construction of the outer skeleton, which becomes stronger, more mineralized and thicker, in comparison to body volume due to incrustation with inorganic compounds [25,26]. For *E. sinensis*, the inorganic compounds constitute almost 40% DW, on average. In addition to climatic differences, other factors had an impact on elemental composition. A higher carbon content was noted in boreal zooplankton as compared to tropical species [25].

The quantities of nitrogen and carbon are, in general, significantly correlated with the total amounts of protein and lipids, respectively. Elemental analyses may be used for indirect estimates of the proximate biochemical composition [22]. The C:N ratio may be used as an index of the lipid/protein ratio [25]. A statistically significant increase ($p < 0.05$, $R = 0.63$) of the energy value along with the increase of the C:N ratio, the value of which varied from 3.6 to 5.8, was observed in *E. sinensis*. No dependence of the C:N ratio on specimen size was observed. Russel-Hunter and Eversole [27] found that C:N ratio of adult specimens is higher than that of juvenile organisms. According to Zhang and Uhlig [23], and Russel-Hunter and Eversole [27], the C:N ratio is strongly affected by nutritional conditions and season, respectively.

It is difficult to evaluate the energy resources of *E. sinensis* in the Baltic Sea, since quantity catch gear fail with this crab. Individuals are mainly caught in fishing nets, where they prey on fish. But because *E. sinensis* is the largest crustacean species living in coastal waters, its presence could have an important impact on the benthic energy resources, even though it appears in Baltic waters periodically while it migrates to its breeding grounds. The claws of *E. sinensis* are relatively small, and contain less meat in comparison to the claws of commercially harvested crayfish *Pacifastacus leniusculus* and *Astacus astacus*, but their interesting look contributes to the often use as a dish decoration.

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