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Cadmium in the shore crab *Carcinus maenas*: seasonal variation in cadmium content and uptake and elimination of cadmium after administration via food

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Abstract

The uptake and assimilation efficiency of cadmium administered via the food in the shore crab *Carcinus maenas* were investigated together with elimination kinetics and seasonal variations in cadmium content. The majority of shore crabs assimilated between 41 and 86% of the cadmium administered in their food. More than 90% of the cadmium taken up from food was retained in midgut gland. Elimination of cadmium after uptake from one meal of radioactively labelled soft parts of blue mussels could be described by a three-compartment model (percent ^{109}Cd-retained = $64 \times e^{-0.001107 \times t} + 25 \times e^{-0.0385 \times t} + 11 \times e^{-0.888 \times t}$). The biological half-life for cadmium in the most slowly exchanging compartment (containing 64% of the body burden) was 626 days. Groups of male and female shore crabs were collected from an uncontaminated site in the period May till October and the concentrations of cadmium in midgut gland and gills were determined. Male crabs had higher cadmium concentrations in the midgut gland in June and August (mean 2.7 μg Cd g^{-1} dry weight) than they had in May, September and October (mean 1.7 μg Cd g^{-1} dry weight). Females generally had slightly lower cadmium concentrations in the midgut gland than the males, except for a relatively high concentration in May. The cadmium concentrations in gills generally ranged between 0.3 and 0.5 μg Cd g^{-1} dry weight) except for male values in October (mean 1 μg Cd g^{-1} dry weight). Some of the seasonal changes in cadmium content of the crabs might plausibly be explained by changes in cadmium uptake from water, i.e. changes during the moult cycle and changes in cadmium uptake rates from water brought about by changes in ambient factors such as salinity and temperature. However, uptake of cadmium from water and transfer to the midgut gland take place at a rate that is two orders of magnitude too low to account for the increase in the cadmium concentrations in midgut gland in male crabs between May and June. The distribution of cadmium among tissues in crabs collected at uncontaminated sites also corresponds better with results obtained after administration of cadmium via the food than via water, and the exposure of the crabs to cadmium via the food is large enough to explain the increase in concentration between May and June.

Keywords: *Carcinus maenas*; Cadmium; Dietary exposure; Assimilation efficiency; Elimination kinetics; Seasonal variation

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1. Introduction

Brachyuran crabs and especially the shore crab *Carcinus maenas* have been used as model organisms in numerous studies on metal uptake and handling (Wright, 1977a, 1977b, 1977c; Jennings and Rainbow, 1979; Jennings et al., 1979; Wright and Brewer, 1979; Bjerregaard, 1982, 1985, 1988, 1990, 1991; Bjerregaard and Depledge, 1994; Martin and Rainbow, 1998; Bondgaard et al., 2000; Styrishave et al., 2000) and this has resulted in a fairly good understanding of the parameters that affect cadmium uptake from the water phase. Cadmium uptake from water in crabs changes with cadmium concentration (Wright, 1977a, 1977b; Jennings and Rainbow, 1979; Bjerregaard, 1990), temperature (O'Hara, 1973; Hutcheson, 2004), salinity (O'Hara, 1973; Hutcheson, 2004; Wright, 1977b; Bjerregaard and Depledge, 1994) calcium concentration (Wright, 1977c; Bjerregaard and Depledge, 1994) crab size (Bjerregaard and Depledge, 1994) and moult (Nørum et al., 2005) and ovarian (Bondgaard et al., 2000) stage and the feeding status of the crabs (Styrishave et al., 2000).

Cadmium taken up from water via the gills (Pedersen and Bjerregaard, 1995, 2000) is transported to the haemolymph and removal of cadmium from the haemolymph by uptake into the midgut gland (Wright, 1977a, 1977b, 1977c; Bjerregaard and Vislie, 1985; Bjerregaard, 1990; Martin and Rainbow, 1998) maintains a lower cadmium concentration in the haemolymph than in the ambient water. In the midgut gland, the majority of the accumulated cadmium is bound in metallothionenins (Jennings et al., 1979; Pedersen et al., 1994, 1998) and inorganic granules (Nott and Nicolaidou, 1994).

Cadmium concentrations in Danish, coastal seawater are approximately 25 ng l^{-1} (Magnusson and Rasmussen, 1982). Most studies on exposure of *C. maenas* to cadmium in the water phase have, however, been carried out at water cadmium concentrations four to five orders of magnitude above the natural background concentrations and they show that cadmium accumulates in the tissues with the highest concentrations appearing in gills and midgut gland followed by hypodermis, exoskeleton and muscles (Wright, 1977a, 1977b, 1977c; Jennings and Rainbow, 1979; Bjerregaard and Vislie, 1985; Bjerregaard, 1982, 1990).

The numerous studies on cadmium uptake from water in decapod crustaceans appear to be in a striking contrast to the number of studies on cadmium uptake from food. *C. maenas* has been shown to assimilate considerable amounts of plutonium (Fowler and Guary, 1977), vanadium (Miramand et al., 1981), americium (Bjerregaard, 1985a, 1985b; Guary and Fowler, 1990), neptunium (Guary and Fowler, 1990), zinc (Chan and Rainbow, 1993) and organic and inorganic mercury (Bjerregaard and Christensen, 1993; Larsen and Bjerregaard, 1995) from food, and Jennings and Rainbow (1979) showed some assimilation of cadmium from a food source although the contribution from food was minimal compared to the contribution from 100 μg Cd l^{-1} in the water phase.

Crabs collected from uncontaminated sites in nature have accumulated the majority of their cadmium body burden in the midgut gland; this has been found for *Cancer pagurus* from Scottish waters (Davies et al., 1981; Falconer et al., 1986) and for *C. maenas* collected around the island of Funen, Denmark (Bjerregaard and Depledge, 2002). As the latter crabs contained approximately 89% of their body burden of cadmium in the midgut gland and only 4–5% in the gills, this distribution among the tissues would seem to be more in accordance with uptake from food than from water.

The present experiments were carried out to elucidate assimilation efficiencies and fate of cadmium accumulated from food in *C. maenas* with the further aim of establishing whether or not food might be an important source for the cadmium accumulated in crabs in uncontaminated coastal areas.

2. Materials and methods

2.1. Chemical analysis

Concentrations of stable cadmium, copper and zinc were determined by atomic absorption spectrophotometry as described by Bjerregaard and Vislie, 1986 and Bjerregaard and Depledge (2002). ^{109}Cd in the tissues of the crabs and in water samples was measured by liquid scintillation counting as described by Bjerregaard (1988). Concentrations of protein and cations in the haemolymph were measured as described by Bjerregaard and Vislie, 1985. Whole-body ^{109}Cd contents were determined with a Bicron well-type