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Cadmium in the purpleback flying squid *Sthenoteuthis oualaniensis* (Lesson, 1830) along northwest coast of India

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Abstract

The purpleback flying squid *Sthenoteuthis oualaniensis* (Lesson, 1830) is landed in small quantities along the northwest coast of India. Keeping in view the possibility of utilization of this species for domestic and export markets, the cadmium accumulation in the body tissues, which often causes concern, was studied. The dorsal mantle length of male and female observed during the study ranged from 34 to 47 cm and 30 to 32 cm respectively. The highest mean concentration of 435.22 ± 61.27 µg g^{-1} (mean ± S.E.) of Cd was found in the liver. Accumulation of Cd was also prominent in the gut, gills and skin. Moderate concentration of Cd (1 to 4 µg g^{-1}) was observed in the nidamental gland, accessory nidamental gland, eyes, tentacles and muscle. In the gonads and arms, the concentration was below the acceptability level of 1.0 µg g^{-1}. Higher accumulation in most of the organs/tissues of larger squids was observed. Significantly higher accumulation ($p < 0.05$) was noticed in the liver of larger specimens, indicating bioaccumulation. As the mean Cd content in the edible part was more than 1.0 µg g^{-1}, this study highlights the need for detailed investigations to understand the bioaccumulation of Cd in *Sthenoteuthis oualaniensis.*

Keywords: Purpleback flying squid, cadmium, tissue, liver

Introduction

Oceanic squids belonging to the family Ommastrephidae are large nektonic predators found mostly in the tropical seas. The Indo-Pacific purpleback squid *Sthenoteuthis oualaniensis* (Lesson, 1830) representing this family is widely distributed in the tropical Indian and Pacific oceans with the productive areas located in 18–22°S northward of Indian Ocean and between 20–25°N and 16–20°S of Pacific Ocean (Aravindakshan and Sakthivel, 1973; Zuyev *et al.,* 2002). Due to their huge biomass and nutritional value, they are prospective subject for open ocean fisheries investigations. This species appears to have a plastic phenotype and has adapted to the Arabian Sea conditions by evolving the capacity to grow to a giant size (Snÿder, 1998). The population density in this region is estimated to be about 0.9-1.6 x 10^6 t (Zuyev *et al.,* 2002). Soviet investigations on cephalopod resources in the Arabian Sea have revealed absolute dominance in numbers and biomass of this species in the epipelagic region (Chesalin and Zuyev, 2002).

In recent years, with the expansion of fishing to the deeper waters, gradual increase in the landings of this species is observed along the northwest coast of India, especially in the Gujarat region. Raje and Savaria (1987) have reported landing of *S. oualaniensis* from Saurashtra coast of Gujarat. Recently, Mohamed *et al.* (2006) have described the population characteristics and some aspects of biology of the purpleback squid landed

at Cochin. As there is lack of knowledge on processing, this oceanic squid remains under-utilized.

In the last decade, there has been a concern on the cadmium accumulation in cephalopods and there are instances of rejection of seafood consignments exported from India because of Cd levels beyond the EU prescribed limit. Squids are known to accumulate Cd from water and food sources and hence constitute an important source of Cd for cephalopod predators and act as vector in the biomagnification process (Bustamante *et al*., 1998). In squids such as *Loligo duvauceli* and *Doryteuthis sibogae* harvested from Indian waters, the mean Cd concentration in the edible parts is found to be within the maximum residual levels prescribed by the EU and USFDA (Prafulla *et al*., 2001; Sivaperumal *et al*., 2007). In cephalopods a differential accumulation of heavy metals in different tissues is reported (Martin and Flegel, 1975; Finger and Smith, 1987). In *S. oualaniensis* from Japanese waters, high cadmium content of 1106 µg. g dry weight^{-1} has been reported from the digestive glands (Kurihara *et al.*, 1993). There is no data on the cadmium content of *S. oualaniensis*, which is now emerging as a fishery along the northwest coast of India. This study attempts to understand the organ/tissue specific accumulation of cadmium in *S. oualaniensis* landed at Veraval, India.

Material and methods

***Squid samples*:** The purpleback flying squid is landed by multiday trawlers along the northwest coast of India, especially by those venturing to the mid-Arabian Sea or closer to the Oman coast. Squid samples were collected from fishing boats operating from Veraval, Gujarat during September 2007 – February 2008. Species identification was based on descriptions of Roper *et al.* (1984) and Silas (1986). Biometric measurements such as dorsal mantle length (DML; in cm) and weight (g) for individual squids were recorded and a total of 30 individuals were used for this study. After initial rinsing with seawater, the samples were sealed in polyethylene bags and kept frozen at -20°C until further analyses. The samples were thawed and dissected on a clean polypropylene board and all individual organs were separated and stored separately. Muscle (edible part), tentacles, arms, gills, accessory nidamental gland, nidamental glands, skin, liver, eyes, gut and gonads were used for studying the cadmium concentration.

Cadmium content analysis: Samples were digested in teflon containers using a microwave digester (Ethos plus High Performance Microwave Labstation, Milestone, USA). Tissues were homogenized, 3g of wet tissue was weighed into 100 ml teflon vials and digested overnight with 7 ml of pure nitric acid (AR grade, specific gravity: 1.38, Qualigens, India) and 3ml of hydrogen peroxide. The microwave parameters were 700W power for one hour (40 minute heating and 20 minute ventilation). The digested contents were transferred to acid washed polypropylene bottles and made up to 25 ml with double distilled water and subjected to Cd analysis in Atomic Absorption Spectrophotometer (GBC 932AA, GBC Scientific Instruments, Australia) by following the AOAC method (AOAC, 2000).

Statistical analyses: One way ANOVA was carried out on log-transformed data on concentration of Cd in the tissues and the significance was tested at 95% confidence level. Whenever significant differences were found, Tukey's posthoc test was used to differentiate between the tissue/organs. Regression analysis was carried out between cadmium concentrations and organ/tissue and for all the samples to find out trend in the accumulation pattern with increase in the size of the individuals. All the statistical analyses were carried out using SPSS software (Version 16.0) (SPSS Inc., USA).

Results and Discussion

The dorsal mantle length ranged between 34-47 cm for males and 30-32 cm for females of *S. oualaniensis*. In earlier studies, the maximum DML for this species has been reported to be 35.0 cm for unsexed specimens (Roper *et al.,* 1984), 62.0 cm for female and 32.0 cm for male (Zuyev *et al.,* 2002). The DML ranges reported by Mohamed *et al.* (2006) from the southern Arabian Sea was 22-47 mm. Chesalin *et al.* (1995) reported giant

Arabian form with mantle length (ML) 24–32 cm (male) and 30–63 cm (female). Xinjun *et al*. (2007) observed mean mantle length of 30 cm for males (range: 10.6–46.2 cm) and 35 cm for females (range: 10.6–61.2 cm).

The concentration of Cd in different organs/ tissue of *S. oualaniensis* is presented in Table 1. The highest mean Cd concentration of 435.22 µg g^{-1} was found in the liver, which ranged from 110.42 to 900.76 µg g^{-1}. High concentrations of heavy metals in the liver (also known as digestive gland, hepatopancreas or mid-gut gland) of ommastrephid squids have been reported earlier (Martin and Flegal, 1975; Smith *et al.,* 1984). In other cephalopods, such as the cuttlefish *Sepia officinalis* and the octopus, *Eledone cirrhosa*, caught along the French coast, the liver contained the highest Cd concentration among the organs (Miramand and Bently, 1992). In a recent study, the highest mean cadmium concentration of 1002.9 µg g^{-1} (wet weight) was observed in the digestive gland of sexually mature Argentine short-finned squids (*Illex argentinus*) (Dornless *et al.,* 2007). In a bioaccumulation study, Koyama *et al.* (2000) observed that the liver of the oval squid *Sepioteuthis lessoniana* exhibited the highest Cd concentration (49.3 µg. g ww^{-1}) and had the highest proportion of Cd content (42.8%) to the whole-body burden at the end of the exposure period of 14 days. The liver of *Sthenoteuthis oualaniensis* accumulating 79 µg. g wet $weight^{-1}$ (Ichihashi *et al.,* 2001) and 780 µg. g dry $weight^{-1}$ (Martin and Flegal, 1975) of Cd has been reported. The protein-bound Cd has been reported to accumulate in the liver of the squid, *T. pacificus* (Tanaka *et al.,* 1983; Dohi *et al.,* 1986). The protein-bound nature of Cd, as reported in the earlier studies, may be the reason for the high concentration of the metal in the liver.

Table 1. Cadmium concentration in the organ tissue of *Sthenoteuthis oualaniensis* (n = 30)

Organ/Tissue	Concentration (µg/g wet weight)		
	Mean ± SD	Minimum	Maximum
Muscle (edible part)	$1.44 \pm 0.29^{a,b,c}$	0.26	5.26
Tentacles	$1.48 \pm 0.30^{b,c,d}$	0.50	4.17
Arms	$0.84 \pm 0.22^{a,b}$	0.27	4.32
Gills	8.92 ± 0.95^{e}	2.95	18.42
Accessory nidamental gland	$1.17 \pm 0.24^{a,b}$	0.15	4.57
Nidamental gland	3.67 ± 0.76^{d}	0.95	12.71
Skin	7.96 ± 0.46^{e}	4.62	13.95
Liver	435.22 ± 61.27^{f}	110.42	900.76
Eyes	$2.94 \pm 0.60^{c,d}$	0.47	8.74
Gut	18.66 ± 3.91^{e}	1.16	47.14
Gonads	0.86 ± 0.24^{a}	0.04	1.86

^{a,b,c,d,e,f} Values with different superscripts are significantly different at $P<0.05$

The mean Cd concentration in the gut of *Sthenoteuthis oualaniensis* was 18.66 ± 3.91 µg g^{-1}. Higher concentration of Cd in the intestine may be due to the occurrence of organisms with high Cd level in the diet and also may be due to frequent cannibalistic tendency of this species (Chesalin, 1994).

In the UK waters, the concentration of Cd was generally higher in the ommastrephids in all the tissues except the muscle (Pierce *et al.,* 2008). In our study, the maximum Cd content in the muscle was 5.26 µg g^{-1}, which is above the prescribed limit for export to EU (EC, 2006) and USA.

Posthoc comparison by one-way ANOVA in different organs of *Sthenoteuthis oualaniensis* showed that the concentration of Cd in the liver

was significantly different from other organs ($p < 0.05$). Skin, gills and gut accumulated moderate to high levels of Cd which was significantly higher than the rest of the organs/tissues.

Regression analysis of Cd concentration in different size showed that the concentration was positively correlated in the case of liver ($p < 0.05$, $r^2 = 0.71$). Cd in other tissues did not show significant trend with increase in size. However, the concentration in most of the organs was higher in larger squids.

Higher Cd content in most of the organs of squids of larger size may be due to the differential feeding pattern with growth. The juveniles mostly devour upon meso and macroplanktonic invertebrates such as the copepods, amphipods and euphausiids, whereas the adults prey upon micronektonic and nektonic organisms such as the myctophids, flyingfishes and squids that may contain higher Cd level in their tissues (Zuyev *et al.,* 2002). Ichihasi *et al.* (2001) reported a similar trend of higher Cd level in the liver of the adult *Sthenoteuthis oualaniensis* (79.1 µg g^{-1}) compared to juveniles (20.8 µg g^{-1}). The result of this study also shows higher concentrations of Cd in the liver (539.9 µg g^{-1}) in 40-50 cm group, than the mean concentrations in 30-40 cm group (185.9 µg g^{-1}).

Table 2. Cadmium concentration (µg g^{-1}) in the organ/ tissue of *Sthenoteuthis oualaniensis* of different length class (n = 30); the values are mean ± SD. NA refers not available

Organ/Tissue	Length (cm)	
	30-40	40-50
Muscle (edible part)	1.38 ± 0.42	1.46 ± 0.37
Tentacles	1.9 ± 1.07	1.38 ± 0.29
Arms	0.65 ± 0.07	0.93 ± 0.32
Gills	08.21 ± 0.44	9.20 ± 1.33
Accessory nidamental gland	0.76 ± 0.07	1.33 ± 0.33
Nidamental gland	2.04 ± 0.380	4.49 ± 1.07
Skin	9.17 ± 1.19	7.47 ± 0.41
Liver	185.98 ± 33.49	534.92 ± 69.74
Eyes	2.62 ± 0.42	3.10 ± 0.89
Gut	28.32 ± 4.08	13.82 ± 5.03
Gonads	NA	0.86 ± 0.24

The present study shows that the Cd is present in the body parts of *S. oualaniensis* and the concentrations are above the maximum permissible limit of 1 ppm for export to the EU countries and USA. Hence, the utilization of the purpleback flying squid landed along Gujarat coast for human consumption needs a cautious approach. Factors like seasonality, metabolic and trophic changes during different life stages, which may alter the accumulation of cadmium, needs further investigations.

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