Tissue Distribution of Domoic Acid in Field-collected Crabs from the California and Oregon Coasts

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Abstract

Federal action levels for domoic acid (DA) in seafood drive federal and state efforts to protect human health. Action levels are tissue-specific, with 30 ppm for Dungeness Crab viscera and 20 ppm for all other seafood, including Dungeness Crab meat. California applies the Dungeness Crab viscera action limit of 30 ppm to Rock Crab viscera. Existing data, including published studies, show that DA preferentially accumulates in viscera of shellfish and finfish. In limited paired testing in California, DA occasionally has been found in crab meat above the 20 ppm threshold; however, this has only occurred when viscera exceeded the 30 ppm threshold. However, the specific range of DA concentrations in viscera at which the crab meat may exceed the action level has not been determined. In this study, DA in paired meat and viscera of Dungeness and Rock crabs from California and Dungeness Crab from Oregon were evaluated to understand the relationship of DA in viscera and meat, and determine whether DA in viscera could be used to predict DA in meat in different species. Our Dungeness Crab data show there is a statistically significant positive association between DA in meat and viscera, consistent with the earlier laboratory study for that species (Schultz et al., 2013). Rock Crab data show a similar pattern, but the smaller sample size is limiting. Further evaluation of this relationship could provide a clearer indication of when both meat and viscera need to be tested for DA.

Background

Domoic Acid: DA is a naturally occurring marine biotoxin that may be produced during "blooms" of some species of the diatom, *Pseudo-nitzschia*. DA is known to accumulate in seafood species including bivalves, crustaceans, finfish, and other invertebrates. Studies in crab (Schultz et al., 2013) and finfish, including coho salmon (Lefebvre et al., 2007), and sardines (Costa and Garrido, 2004; Mazzillo, Pomeroy et al., 2010), document preferential accumulation of DA in the internal organs, with less frequent and lower detections in muscle tissue.

Domoic Acid Monitoring in California and Oregon Seafood

State agencies in California and Oregon work to obtain seafood samples from volunteers and the commercial operators who grow or harvest seafood. Dungeness Crab are primarily harvested in Oregon and Northern and Central California, with Rock Crab harvest predominating in Southern California. Tissue concentrations of DA are compared to the action levels, with 30 ppm for Dungeness Crab viscera and 20 ppm for all other seafood, including Dungeness Crab meat. State health agencies determine the appropriate actions needed to protect human health. When DA concentrations exceed action levels in viscera or meat, health agencies may close a fishery, issue an advisory to not consume the viscera, or order evisceration.

Key References

- Costa, P. R. and S. Garrido (2004). "Domoic acid accumulation in the sardine *Sardina pilchardus* and its relationship to *Pseudo-nitzschia* diatom ingestion." Marine Ecology Progress Series 284: 261-268.
- Lefebvre, K. A., et al. (2007). "Uptake, tissue distribution and excretion of domoic acid after oral exposure in coho salmon (*Oncorhynchus kisutch*)." Aquat Toxicol 81(3): 266-274.
- Mazzillo, F. F. M., et al. (2010). "Angler exposure to domoic acid via consumption of contaminated fishes." Aquatic Biology 9(1): 1-12.
- Schultz, I. R., et al. (2013). "Domoic acid toxicokinetics in Dungeness crabs: new insights into mechanisms that regulate bioaccumulation." Aquat Toxicol 140-141: 77-88.
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Methods

California Dungeness and Rock Crab Sample Collection and Analysis: The California Department of Public Health (CDPH) and the California Department of Fish and Wildlife (CDFW) work with the commercial crab fleet in California to obtain Dungeness Crab samples prior to the opening of the fishing season, and Rock Crab samples, as available, given the year-round fishery. Seafood samples are analyzed for DA at the CDPH laboratory by high performance liquid chromatography with a method detection limit of 2.5 mg/kg. The viscera is analyzed first, and the meat is subsequently analyzed if the viscera DA concentrations are elevated (on a case by case basis).

Oregon Dungeness Crab Sample Collection and Analysis: The Oregon Department of Agriculture (ODA) works with the commercial crab fleet in Oregon to obtain Dungeness Crab samples prior to the opening of the crab fishing season, as well as during the season when DA levels are elevated in indicator species. Seafood samples are analyzed for DA at the ODA laboratory by high performance liquid chromatography with a method detection limit of 1.0 mg/kg. The viscera is analyzed first, and the meat is subsequently analyzed if the viscera DA concentrations are elevated. The November 2017 ODA administrative rules require meat samples be analyzed if viscera DA levels are detected at or above 30 ppm.

Evaluation of Paired Viscera and Meat Domoic Acid Data: The California Office of Environmental Health Hazard Assessment (OEHHA) staff obtained DA concentration data for the available paired viscera and meat samples (from the same individual) from CDPH and ODA. Data were evaluated for each species when a sufficient number of samples were available (Dungeness and Rock crabs). Only data for which DA was detected above the method detection limit in both viscera and meat for the same individual were included. Comparisons between source and tissue types, and regression models of paired meat and viscera were evaluated using the Microsoft Excel Data Analysis ToolPak.

Estimation of Viscera "break-through" threshold: Schultz et al., 2013, estimated the storage capacity of the hepatopancreas, and the concentration at which "break-through" to other tissues was likely. We extrapolated a viscera concentration at which "break-through" was predicted by utilizing the same assumptions (hepatopancreas 3.46% of body weight and 50% dose stored in tissue), and included an estimate of the relative proportion of viscera that is hepatopancreas (21%).

Conclusions

- For this data set, viscera and meat DA concentrations were higher in California than Oregon for Dungeness Crab, and higher in the viscera of California Rock Crab compared to Dungeness Crab (**Figures 1 and 3**). This is generally consistent with geographic variations in the occurrence of DA in the environment (Smith et al., 2018).
- Increasing meat DA concentrations occurred at or above the estimated viscera "break-through" threshold range for Dungeness Crab in the model adapted from Schultz et al. (2013) (**Figure 2**).
- The relationship between DA in meat and viscera was statistically significant for both Dungeness and Rock crabs (**Figures 2 and 4**). Based on the linear regression models, meat of Dungeness Crab (following log transformation) and Rock Crab are predicted to exceed 20 ppm at viscera concentrations of 187 and 171 ppm, respectively. However, the lowest viscera concentrations at which paired meat samples were 20 ppm or higher occurred at 46 and 93 ppm for Dungeness and Rock crab, respectively (**Tables 1 and 2**).
- Additional samples will be incorporated, as available, into these evaluations to further understand the relative tissue distribution of DA in crabs, and inform sample analysis decisions.

Results — Dungeness Crab from CA and OR

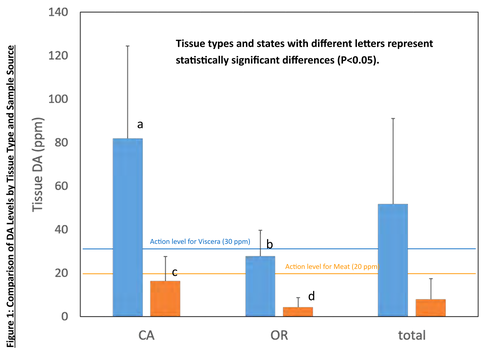

Figure 1: Comparison of DA Levels by Tissue Type and Sample Source

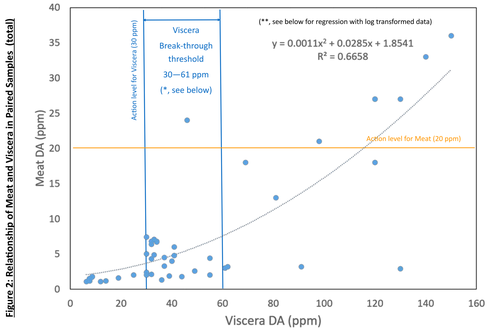

Figure 2: Relationship of Meat and Viscera in Paired Samples (total)

* Tissue "break-through" thresholds (in ppm DA)
- Hepatopancreas (HP): range 145— 290 (Schultz et al., 2013)
- Viscera: range 30— 61 (adapted from Schultz et al., 2013 with HP as 21% of viscera)

** Linear regression model for log transformed meat and viscera (CA and OR combined)
- y = 0.9368x - 0.8274, R^2 = 0.5548; p<0.05

Table 1: Dungeness Crab Data

Dungeness Crab (detects only)	Viscera (ppm DA)		Meat (ppm DA)		Meat/Viscera (%)	
Source (sample size)	Range	Average	Range	Average	Range	Average
CA (n=17)	30-150	81.9	3.0-36	16	4-52	20
OR (n=29)	6.3-130	34.2	1.1-7.1	3.1	2-22	11
Total (n=46) (CA and OR combined)	6.3-150	51.8	1.1-36	8.0	2-52	15
Subset with meat DA above 20 ppm action level CA/Total (n=7)	46-150	115	21-36	28	21-52	27

Results — Rock Crab from CA

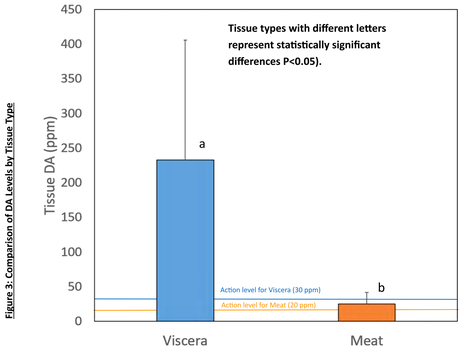

Figure 3: Comparison of DA Levels by Tissue Type

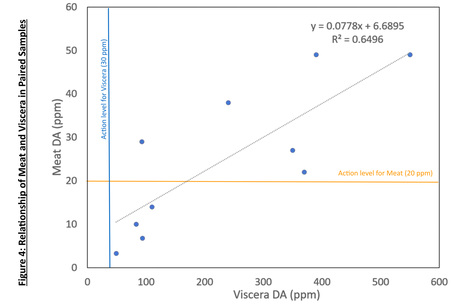

Figure 4: Relationship of Meat and Viscera in Paired Samples

Table 2: Rock Crab Data

Rock Crab (detects only)	Viscera (ppm DA)		Meat (ppm DA)		Meat/Viscera (%)	
Source (sample size)	Range	Average	Range	Average	Range	Average
CA (n=10)	49-550	233	3.3-49	25	5.9-31	12
Subset with meat DA above 20 ppm action level CA (n=6)	93-550	332	22-49	36	5.9-31	14

Contact Information and Acknowledgments

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