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In vivo effect of metals in clams *Ruditapes decussatus*: A multi-marker approach

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INTRODUCTION & AIM

Ruditapes decussatus, **a bivalve mollusc, represents an important natural resource of considerable ecological and economic value. Its sustainable exploitation is of great interest due to its high nutritional protein content and its role as a sentinel species in the biomonitoring of aquatic pollution. In natural ecosystems, venericulture constitutes one of the main aquaculture activities practiced in Lake Mellah.Heavy metal contamination is a major environmental concern in aquatic ecosystems, as metals such as cadmium (Cd) and copper (Cu) can induce oxidative stress and metabolic disturbances in marine organisms. In this context, a multi-biomarker approach provides an effective tool for assessing the biological effects of metal exposure in order to test the hypothesis that these contaminants induce tissue-specific alterations related to oxidative stress and energy metabolism.**

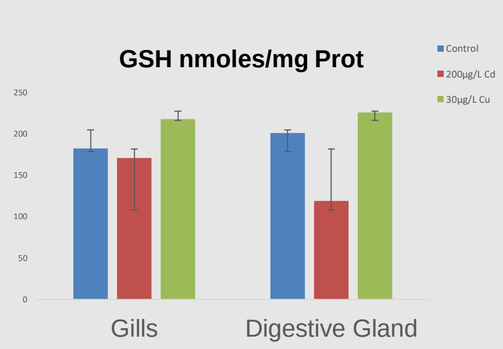
METHOD

Specimens of *Ruditapes decussatus* were collected from the Hnaya region (western Annaba, Algeria), acclimated for 48 h, and then exposed for seven days in triplicate experimental conditions (three aquaria, six individuals per aquarium) to 200 µg/L Cd and 30 µg/L Cu. These concentrations were selected based on published data, representing polluted coastal environments, and are commonly used in laboratory ecotoxicological studies to induce measurable biochemical responses under short-term exposure. Experimental conditions were maintained constant (16 ± 2 °C; salinity: 37 psu; photoperiod: 12 h light/12 h dark), with regular renewal of seawater and metal solutions. Gills and digestive glands were analysed for reduced glutathione (GSH), lipid peroxidation (MDA), total lipids, and proteins. Data were analysed using two-way ANOVA followed by appropriate post hoc tests ($p < 0.05$).

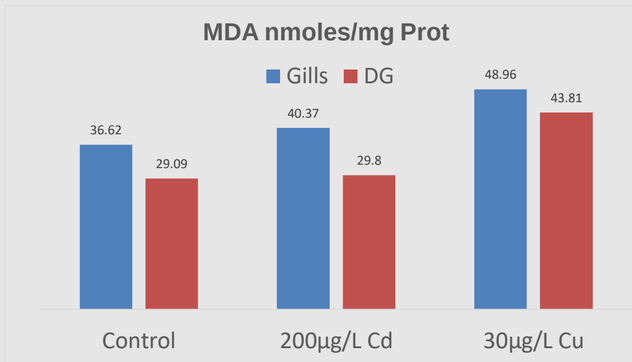
CONCLUSION

Overall, these results highlight the involvement of multiple antioxidant defense pathways and emphasize the complexity of the interactions between oxidative stress and energy metabolism in *Ruditapes decussatus.* The multi-biomarker approach adopted therefore provides a better understanding of the adaptive mechanisms developed by marine organisms in response to metal contamination.

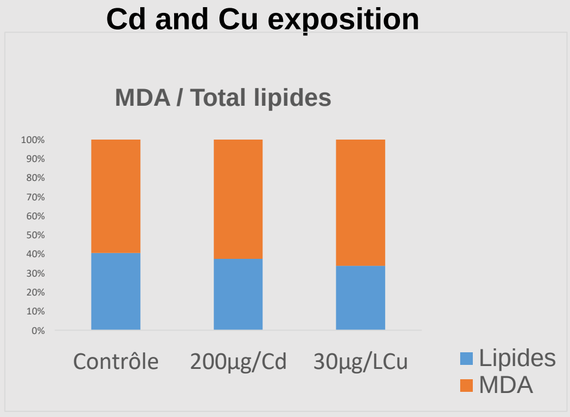
RESULTS & DISCUSSION



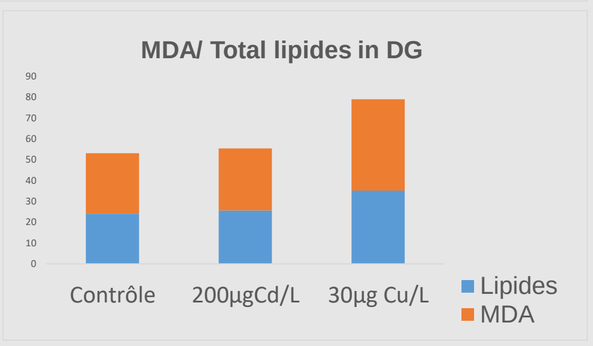
Variations of GSH level inder Cd and Cu exposition



Variations of MDA level inder Cd and Cu exposition



Relation between the variations of MDA levels (nmol/mg prot.) and totals lipids (µg/g) in Gills



Relation between the variations of MDA levels (nmol/mg prot.) and totals lipids (µg/g) in DG

The present results highlight tissue-specific biochemical responses of *Ruditapes decussatus* exposed to cadmium (Cd) and copper (Cu), reflecting distinct adaptive and oxidative stress mechanisms. Glutathione (GSH), one of the major non-enzymatic antioxidants, showed differential variations depending on both tissue and metal. In the gills, GSH levels slightly decreased under Cd exposure but increased under Cu exposure, suggesting an activation of antioxidant defenses to counteract reactive oxygen species (ROS) production. In the digestive gland, Cd induced a strong depletion of GSH, which may indicate its intensive utilization in detoxification processes. However, Cu exposure stimulated GSH accumulation, probably reflecting an adaptive response aimed at maintaining cellular redox homeostasis. MDA levels increased significantly in the digestive gland under both Cd and Cu exposure, with the strongest increase observed under Cu treatment. In the gills, however, only Cu induced a marked elevation of MDA, while Cd had little effect. These results suggest that Cu exerts stronger pro-oxidant effects than Cd, likely due to its redox-active nature and its ability to directly generate ROS through Fenton-like reactions. Lipid content remained relatively stable in the gills under both metal exposures, indicating limited disturbance of energy storage in this tissue. In contrast, the digestive gland exhibited increased lipid levels, particularly under Cu exposure. This accumulation may reflect enhanced lipid synthesis as part of an adaptive strategy to cope with metal stress. Overall, the combined variations of GSH, MDA, and lipid reserves reveal a complex interaction between antioxidant defense systems and energy metabolism in response to metal contamination. The digestive gland appears to be the most responsive and vulnerable tissue, acting as a major site of detoxification and metabolic adjustment, while Cu induced more pronounced oxidative disturbances than Cd. These findings confirm the usefulness of a multi-biomarker approach for understanding the physiological adaptations of marine bivalves under metal stress.

FUTURE WORK / REFERENCES

Future studies should focus on the combined assessment of malondialdehyde (MDA), metallothioneins (MT), and antioxidant system responses, as these biomarkers may represent valuable tools for the biomonitoring of heavy metal contamination.