Deciphering mercury and selenium interactions in fish: a kinetic comprehensive speciation and isotopic study in rainbow trout with tuna-based diets

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Context

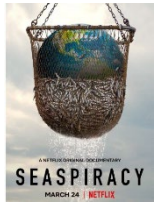
Aquaculture

*one of the **fastest growing industry***

8% yearly increases in the last 10 years (FAO)

increased demand for aquafeeds

new alternatives to developing sustainable fishmeal



solid wastes generated by the tuna canning industry: up to 65%

fish byproducts

Plant based diet

- ~25.5 kg **tuna** Per capita fish consumption/year
- the **most-consumed** product in the EU
- the **high (Me)Hg concentrations**

…but also high Se levels

- **Hg and Se dietary fate**
- **Potential valorisation of tuna by-products**

?

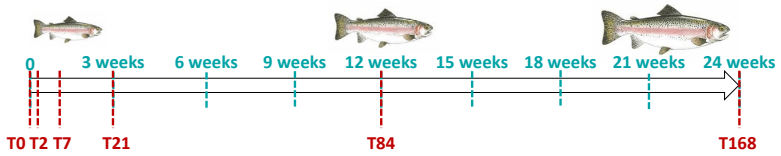
model aquaculture fish species
rainbow trout (*Oncorhynchus mykiss*)

2nd fish species produced in Europe

Understanding mercury-selenium interactions in fish

Tuna byproducts, plant-based diets

+ MeHg
+ Se(IV)
+ Se-Methionine



model aquaculture fish species

rainbow trout (*Oncorhynchus mykiss*)

Brain
Liver
Muscle
Kidney
Blood

12 dietary conditions

Tuna meal-based diets

	Se (µg g^{-1})	**Hg** (µg g^{-1})
Control	8.0 ± 0.2	0.25 ± 0.02
Se(IV)	10.3 ± 0.6	0.19 ± 0.03
SeMet	10.3 ± 1.2	0.21 ± 0.02
MeHg	7.8 ± 0.3	2.13 ± 0.04
Se(IV)+MeHg	11.2 ± 1.4	2.2 ± 0.1
Se(IV)+MeHg	10.3 ± 0.9	2.0 ± 0.1

Plant-based diets

	Se (µg g^{-1})	**Hg** (µg g^{-1})
Control	0.25 ± 0.01	< LOD
Se(IV)	3.5 ± 0.2	< LOD
SeMet	2.3 ± 0. 1	< LOD
MeHg	0.28 ± 0.01	2.6 ± 0.2
Se(IV)+MeHg	2.3 ± 0.1	2.5 ± 0.1
Se(IV)+MeHg	2.2 ± 0.1	2.4 ± 0.2

80% of Se: naturally present in tuna byproducts

Aquaculture, 2023, 572, 739550

$\delta_{Hg,}$

ISOTOPIC « FINGERPRINT »
(MC-ICPMS)

- ***life history***
- ***(pollution) source***
- ***reaction tracking***

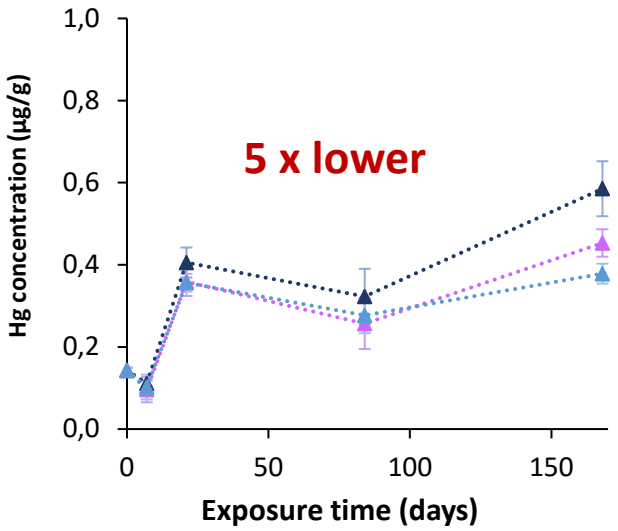
TOTAL (Hg, Se)
CONCENTRATION

Hg and Se SPECIATION
(GC-ICPMS, HPLC-ICP-MS/ESI-MS)

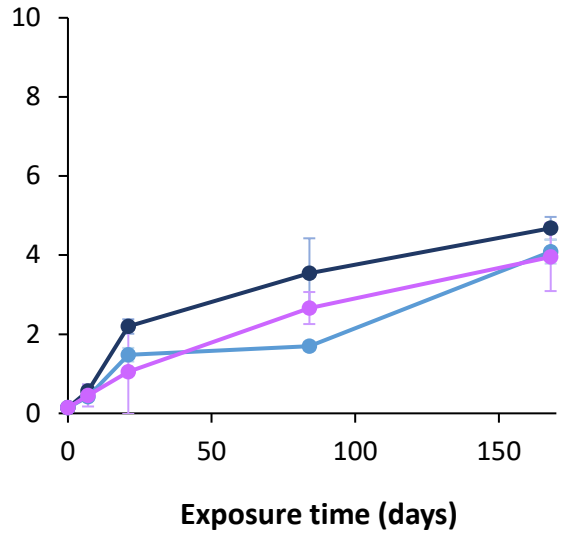
Understanding mercury-selenium interactions in fish

Resulting Hg concentration in muscle

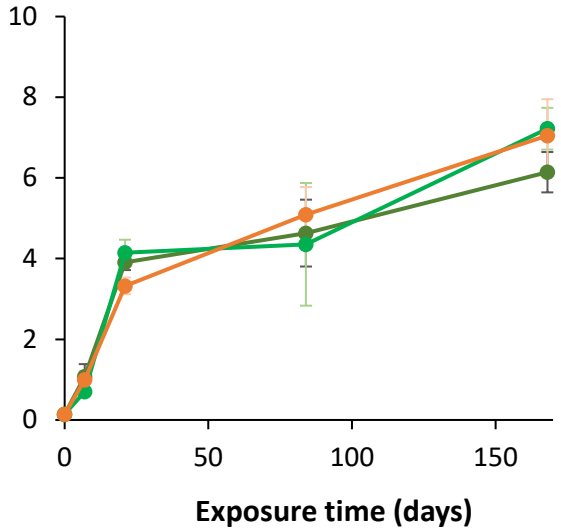
Dietary exposed to tuna byproducts



Dietary exposed to tuna byproducts + (2.5 (µg g^{-1}) MeHg



Dietary exposed to plant based diet + (2.5 (µg g^{-1}) MeHg



Hg level below the threshold established for human consumption (3 µg g^{-1} dw)

Safe consumption

= MeHg dietary exposure levels

≠ Hg bioaccumulation

Is it due to the Se naturally present in the tuna byproducts?

Food Chemisry 2024, 447,138865

Effect of dietary Se (species) Hg bioaccumulation

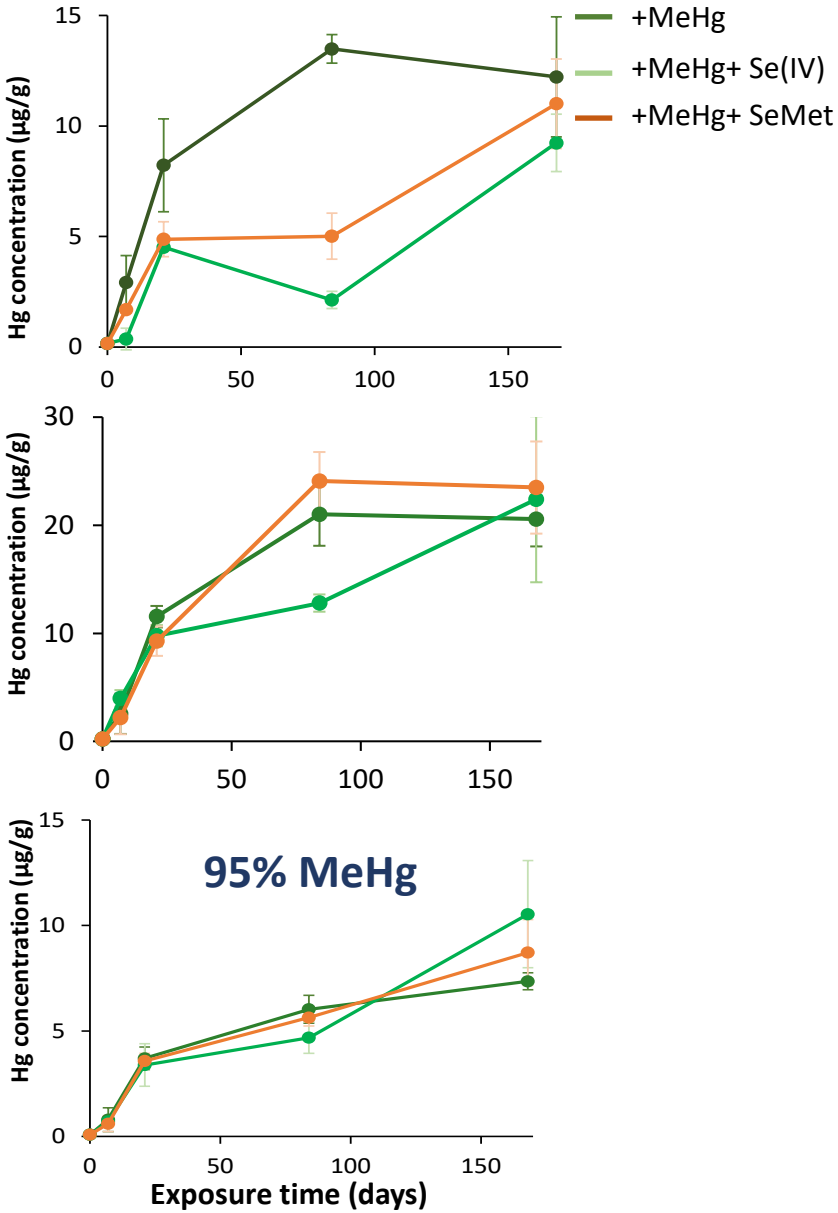
Dietary exposed to plant based diet + MeHg

Dietary exposed to tuna byproducts + MeHg

Liver

Blood

Brain



✓ **In general, tuna byproducts diets result in lower Hg levels**

Fate of dietary Se

Dietary exposed to plant based diet

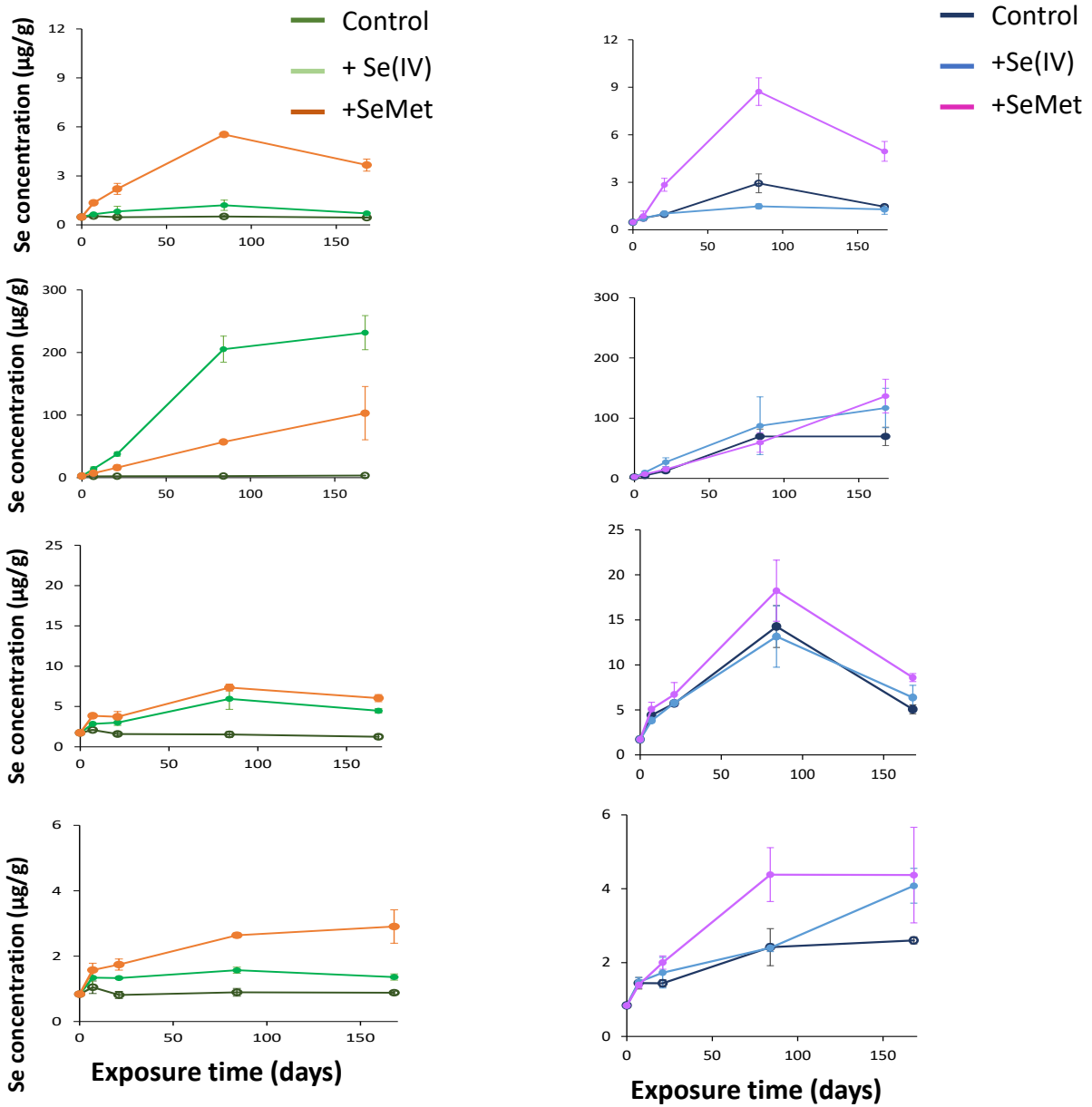
Dietary exposed to tuna byproducts

Muscle

Liver

Blood

Brain



✓ **Tuna byproducts based diets lead to higher Se bioaccumulation (except in liver)**

✓ **Differences of Se bioaccumulated <<< than the Se dietary content**

Regulation of tuna basal Se?

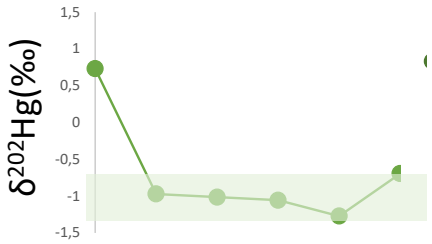
Dietary SeMet > Se in muscle and brain

Kinetic Hg isotopic signature in fish

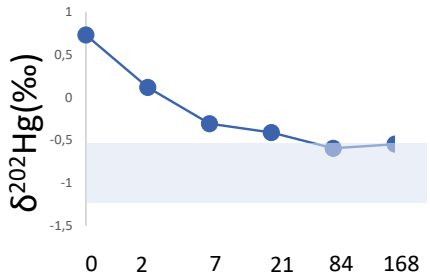
$\delta_{Hg,}$

Fed with plant based diets

Blood



Fed with tuna based diets



Exposure time (days)

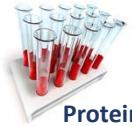
✓ **Faster Hg bioaccumulation from plant diets than from tuna byproducts**

Role of Se naturally present in tuna byproducts?

Queipo-Abad et al. In prep.

Screening of Hg and Se in the water soluble protein fraction


USP


Protein extract

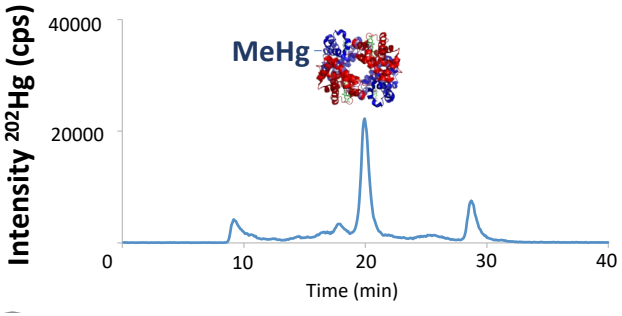

HPLC-ICP-MS/ESI-MS


Fed with tuna based diets


Trophic transfer evidence!

Hg (liver)

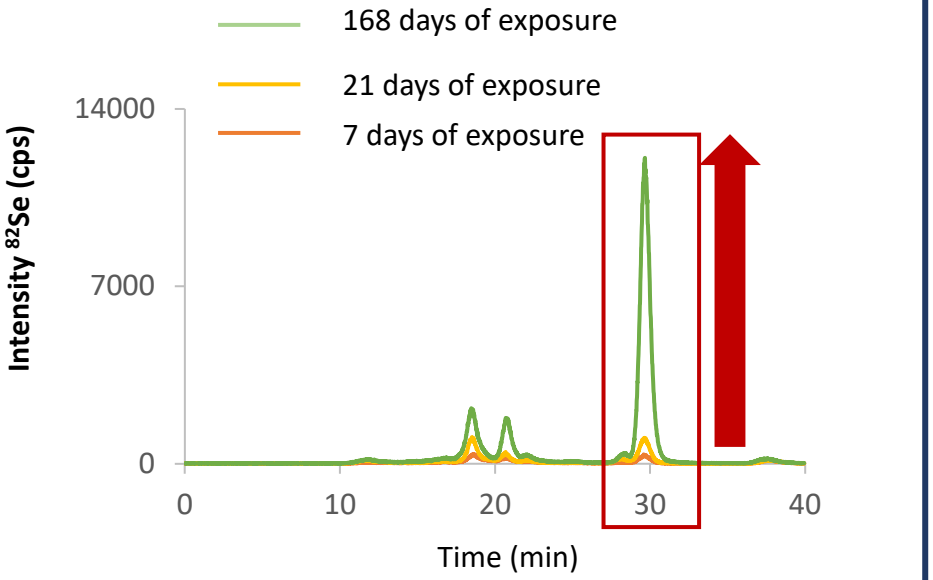
21 days of exposure

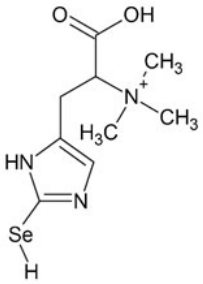


✓ MeHg kinetically transferred from Hb to low molecular weight compounds

involved on storage and/or detoxification?

Se (blood)





Increases of Selenoneine fraction with the exposure time

Journal of Hazardous Material (under revision)

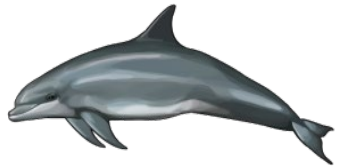
First-time selenoneine identification in freshwater fish

blood, muscle

Yamashita et al. J. Biol. Chem. 2010

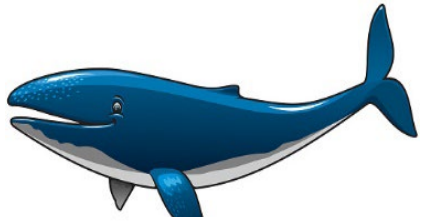
blood, urine

Klein et al. Metallomics 2011, Achouba et al. Chemosphere 2019, Kroepfl et al. JAAS 2019



liver

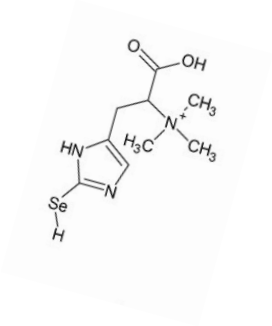
Anan et al. JAAS, 2011; Pedrerp et al. 2014

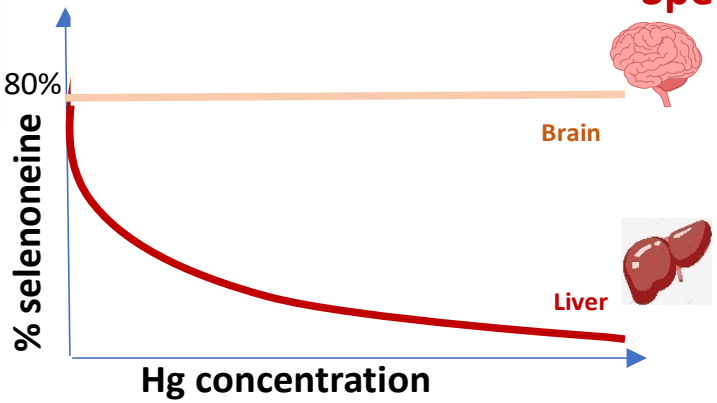


skin

Achouba et al. Chemosphere 2019

Role?





Specific role(s) in the nervous system?

Involved in MeHg demethylation?

Environ. Sci. Technol. 2022, 56, 3288−3298

Journal of Hazardous Materials, 2022, 425, 127922

Conclusions and perspectives

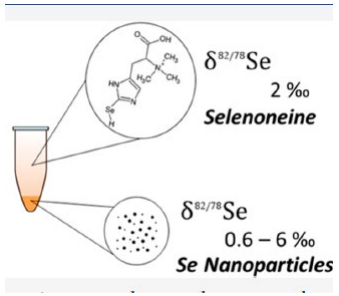
- **Tuna byproducts-based diets resulted in muscle Hg content below the threshold established for human consumption**

- **Basis for the future use of tuna byproducts as an alternative protein source for the development of sustainable aquafeeds.**

Hg bioaccumulation depends on dietary Se species and not on total Se content!

Perspectives

δSe



Environ. Sci. Technol. July 2024

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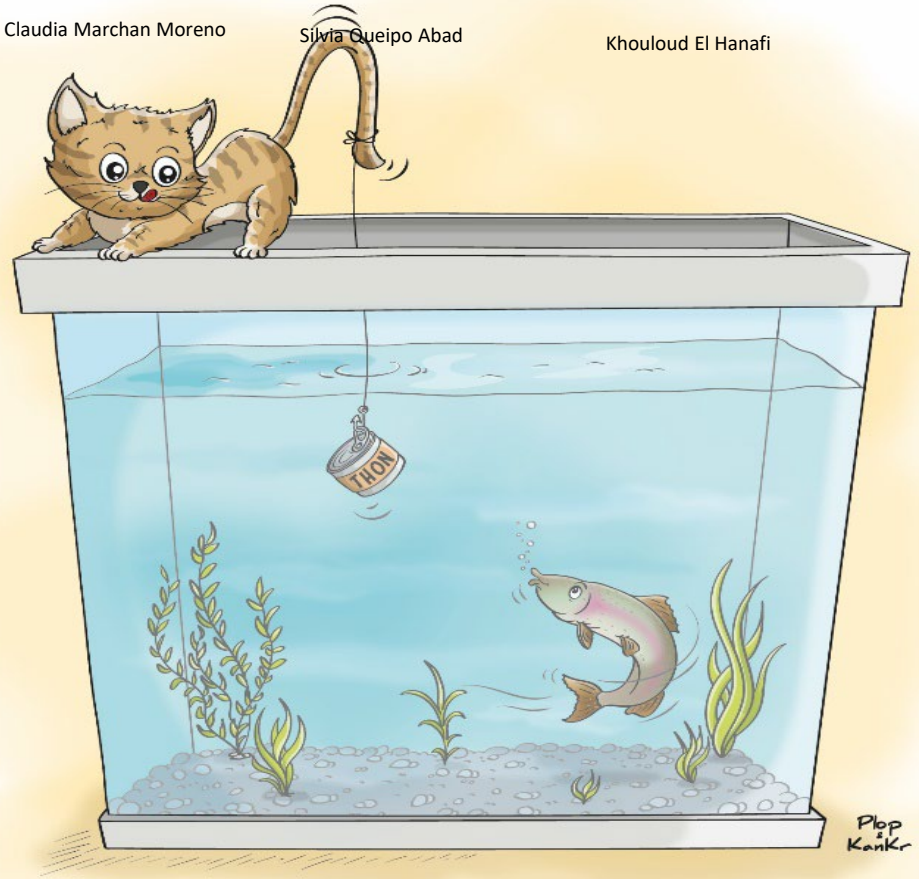

Thank you for your attention!

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