Nutrition of **Meagre (*Argyrosomus regius*): Advances in larval and juvenile nutrition.**

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WP 8. Nutrition in Meagre

Grupo de Investigación en Acuicultura

***Objective*:** to better define the nutritional needs of meagre during both pre-growing and on-growing phases to improve growth consistency and fish health and welfare

Task 8.1. Improvement of larval weaning feeds (Led by FCPCT-ULPGC)

Task 8.2. Determination of nutritional requirements to promote feed utilization, growth and welfare (Led by FCPCT- ULPGC)

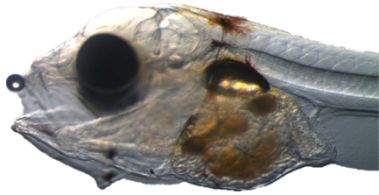
WP 8. Nutrition in Meagre

- **Task 8.1. Improvement of larval weaning diets**

  1. Optimum essential fatty acids and related micronutrient levels in weaning diets for meagre

  2. Importance of dietary vitamins A, K and D in weaning diets for meagre

  3. The importance of Vitamin K in quality of meagre fry



- **Task 8.1**. Improvement of larval weaning diets.

  1. **essential fatty acids + micronutrients**

Table 1. Variable ingredients and proximate composition (g 100 g^{-1}dw) of early weaning diets containing several n-3 HUFA, vitamin E and vitamin C levels fed to meagre (*A. regius*) larvae from 14 to 28 dah.

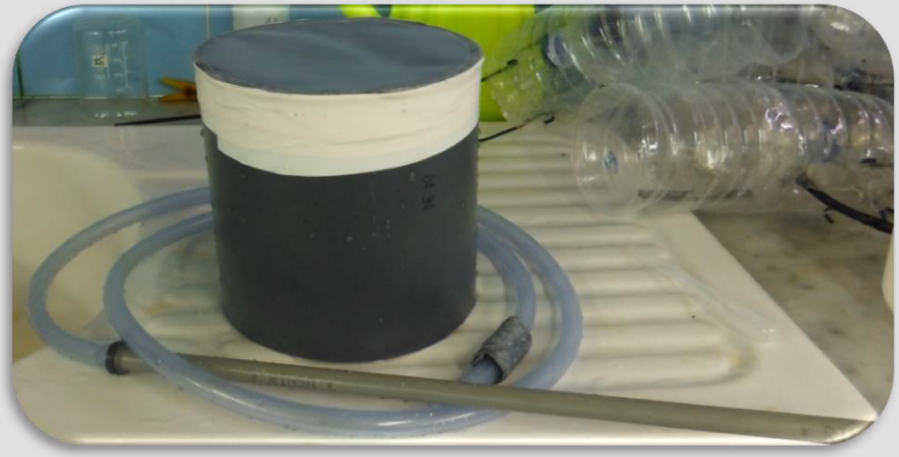
	Diets					
	0.4/150/180	**0.4/300/180**	**0.4/300/360**	**3/150/180**	**3/300/180**	**3/300/360**
Ingredients						
Peruvian anchovy oil	0.00	0.00	0.00	10.00	10.00	10.00
Oleic acid[a]	10.00	10.00	10.00	0.00	0.00	0.00
Vitamin E*	150.00	300.00	300.00	150.00	300.00	300.00
Vitamin C*	180.00	180.00	360.00	180.00	180.00	360.00
Proximate composition						
Lipid	16.01	17.09	17.06	17.52	17.34	17.44
Protein	65.14	64.72	64.97	65.43	65.45	64.88
Moisture	10.32	10.59	9.38	9.67	9.39	9.35
Ash	5.47	5.55	5.70	5.88	5.73	5.81

Experimental design

Material & Methods

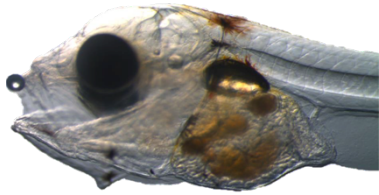
3000 larvae in 15 tanks (200l)
17 dph-33 dph
16 days of feeding

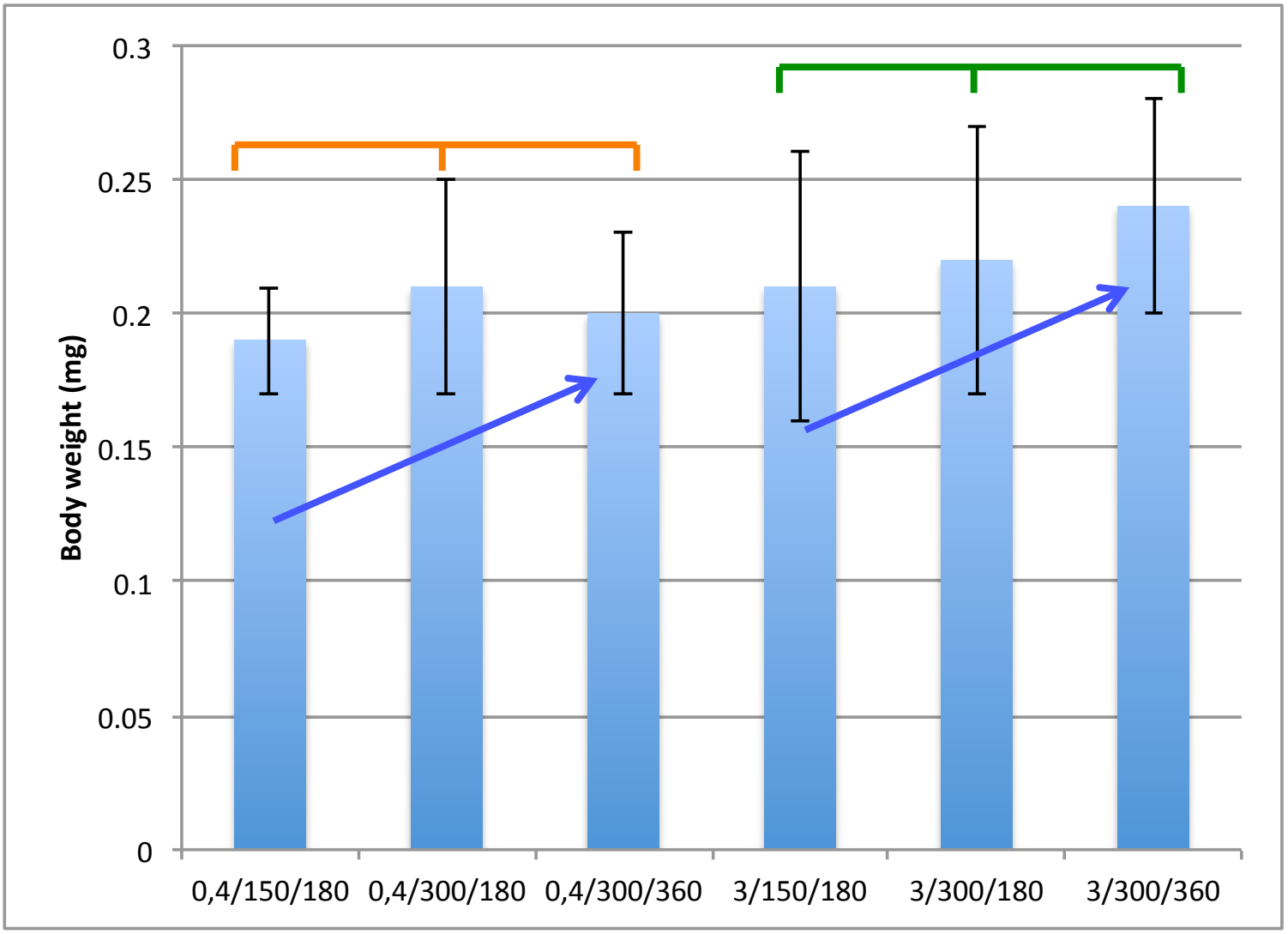
Daily tasks:
Tª, O_2 ,Saturation, Siphoning, Skimmer
Daily Mortality



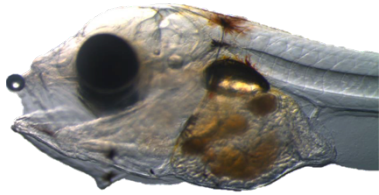
Feeding routine:
Every 45 min
From 8 am to 7pm

- **Task 8.1**. Improvement of larval weaning diets.
  1. essential fatty acids + micronutrients

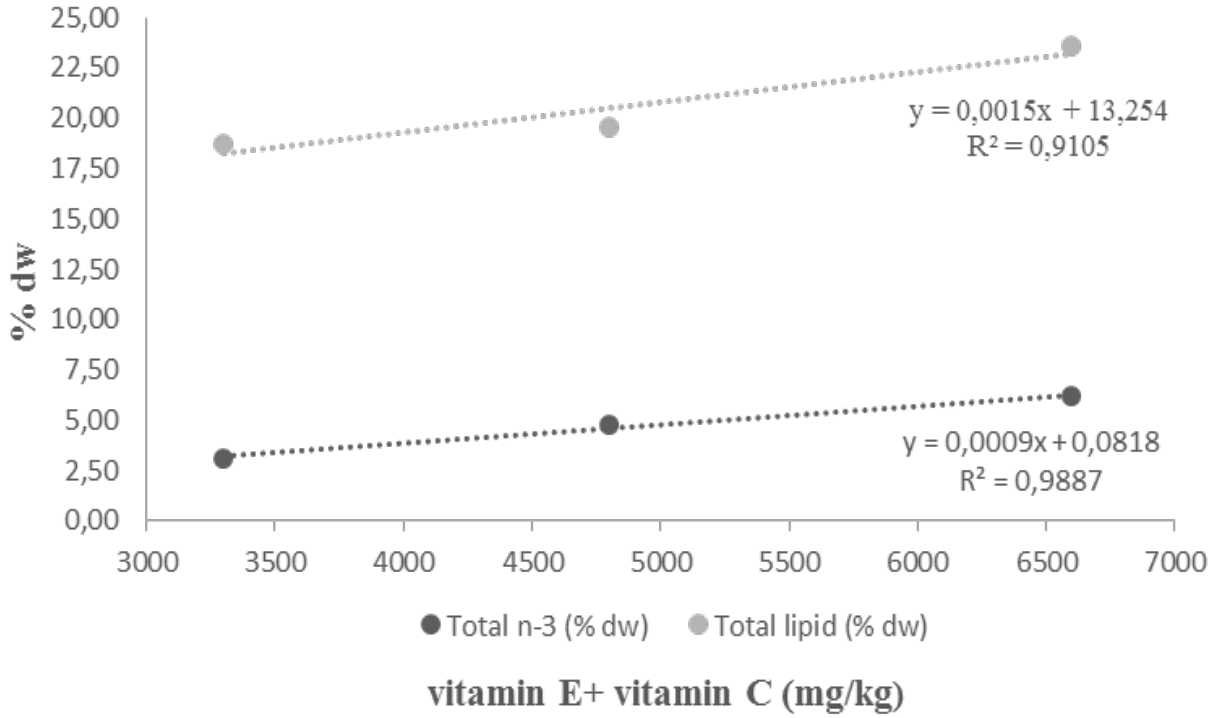




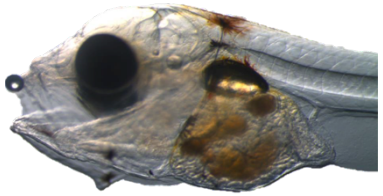
- **Task 8.1**. **Improvement of larval weaning diets**.
  1. essential fatty acids + micronutrients

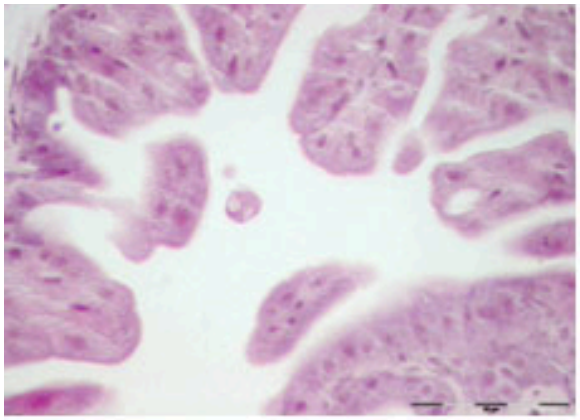


Effect of dietary vitamin E and C on lipid and n-3 contents (dw) in meagre (*A. regius*) larvae after 14 days of feeding 3% HUFA diets

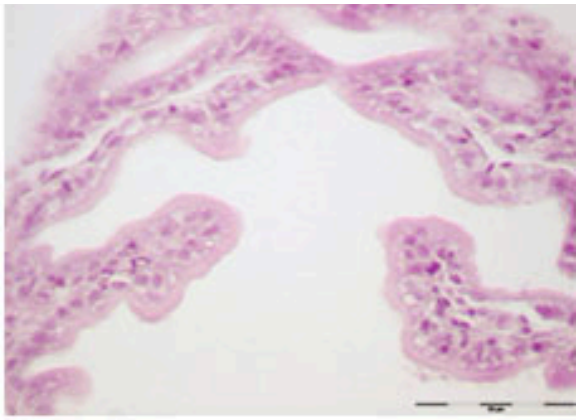


Morphological study
H&E stain



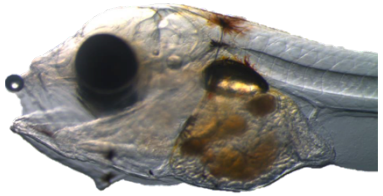


Intestine of larvae 0.4/150/180 (40X) scarce lipid vacuoles accumulation in the enterocytes;

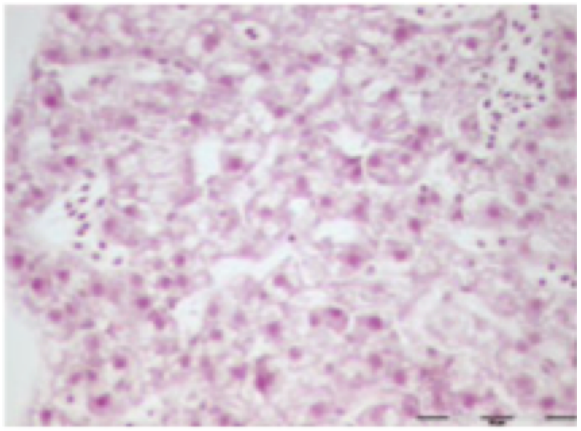


Intestine larvae 3/150/180 (40X) large lipid vacuoles around the nucleus and in the basal part of the enterocytes;

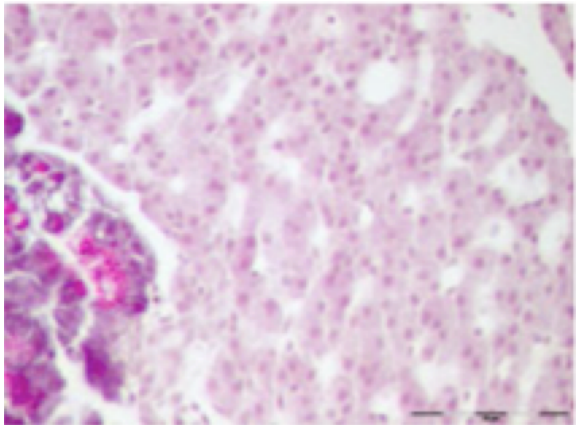
Increased lipid mobilization

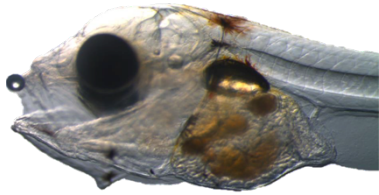


liver larvae 0.4/ 150/180 (40X) hepatocytes with high lipid vacuoles deposition



liver larvae 3/150/180 (40X) condensed hepatocytes with centred nucleus and marked cytoplasm staining;



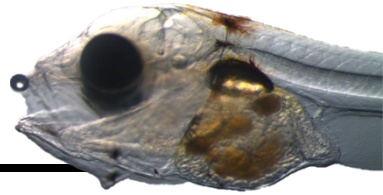


- **Task 8.1**. **Improvement of larval weaning diets**.
  1. essential fatty acids + micronutrients

✓ 0.4% dietary HUFA is not enough to cover the essential fatty acid requirements of larval meagre and, since their elevation up to 3% markedly improved lipid absorption, essential fatty acids levels and growth, a high HUFA requirement in weaning diets is foreseen for this species.

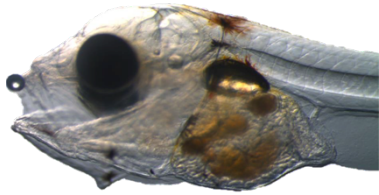
✓ pointed out the importance of dietary vitamin E and vitamin C to protect these essential fatty acids from oxidation, increase their contents in larval tissues and promote growth, suggesting as well high vitamin E and vitamin C requirements in meagre larvae (higher than 1500 and 1800 mg kg^{-1} for vitamin E and vitamin C, respectively).

- **Task 8.1**. Improvement of larval weaning diets.
  2. **Vitamins A, K & D**



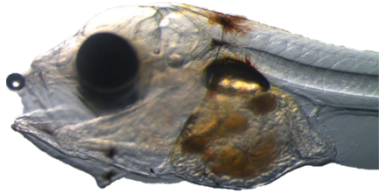
	Diets				
	C	**C+Taurine**	**C-Vit K**	**C-Vit D**	**C-Vit A**
Ingredients					
Taurine[i]	0.0	200.0	0.0	0.0	0.0
Vit K[j]	17.3	17.3	0.0	17.3	17.3
Vit D[k]	3.7	3.7	3.7	0.0	3.7
Vit A[l]	0.3	0.3	0.3	0.3	0.0
Proximate composition (%)					
Crude lipids	16.4	16.2	16.5	17.1	17.9
Crude protein	76.0	75.9	76.4	76.4	76.1
Moisture	13.7	13.6	13.6	13.8	13.8
Ash	6.5	6.5	6.5	6.6	6.5
Taurine[1]	4.0	5.8	4.0	4.0	4.0
Vitamin K[2]	2.4	2.4	0.0	2.6	2.2
Vitamin D[3]	28.9	29.0	30.4	2.3	27.4
Vitamin A[4]	4.2	4.3	4.2	4.3	4.1

- **Task 8.1.** Improvement of larval weaning diets.
  2. Vitamins A, K & D



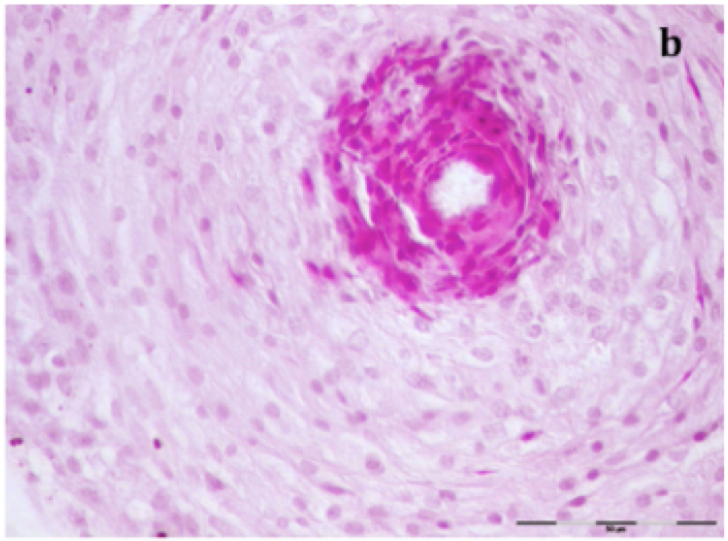
		Diets				
		C	C+Taurine	C-Vit K	C-Vit D	C-Vit A
Total length	26 dah	8.3±1.0 [a]	8.5±0.9 [a]	8.5±1.0 [a]	8.9±1.0 [b]	8.6±1.0 [a]
	33 dah	11.5±1.7 [a]	11.7±1.3 [a]	12.8±1.6 [b*]	12.6±1.3 [b]	12.2±1.7 [b]
Body weight	26 dah	0.7±0.1 [a]	0.8±0.1 [a]	0.7±0.1 [a]	0.9±0.2 [b]	0.8±0.2 [a]
	33 dah	2.4±0.6 [a]	2.3±0.4 [a]	3.2±0.2 [b*]	3.3±0.2 [b]	2.5±0.3 [a]
Survival (%)		16.7±6.5	12.9±1.2	7.1*	17.7±12.3	19.0±0.5

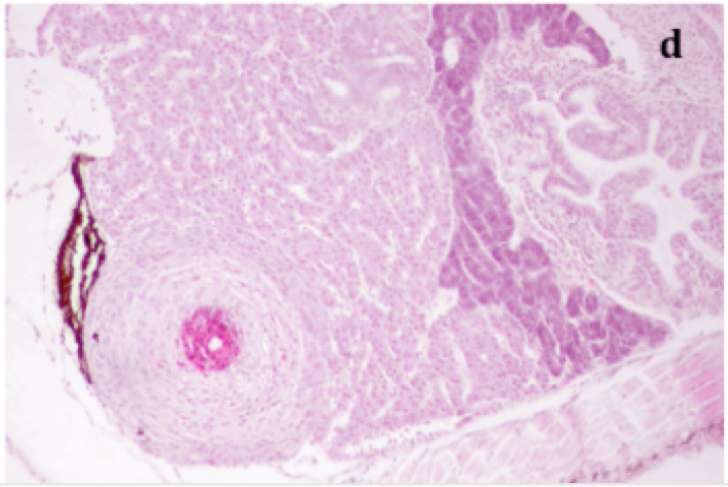
- Task 8.1. Improvement of larval weaning diets.
  2. Vitamins A, K & D



Effect on systemic granulomatosis

	33 dah		
Diets	Total	Stage I	Stage II
C	0.0±0.0	0.0±0.0	0.0±0.0
C+Taurine	0.0±0.0	0.0±0.0	0.0±0.0
C-Vit K	12.5±10.6	5.0±7.1	7.5±3.5
C-Vit D	3.3±2.9	1.7±2.9	1.7±2.9
C-Vit A	8.3±10.4	6.7±7.6	1.7±2.9

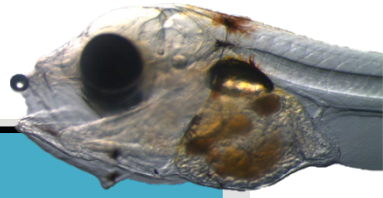




- Task 8.1. Improvement of larval weaning diets.
  2. Vitamins A, K & D

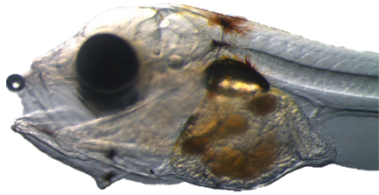
- ✓ supplementation of meagre weaning diets with 2.4 mg/kg vit K, since the absence of this vitamin markedly reduced larval survival.
- ✓ very sensitive to hypervitaminosis D and, only midly to hypervitaminosis A, since supplementation with these vitamins leaded to a growth reduction.
- ✓ taurine supplementation did not have any effect in meagre larvae performance

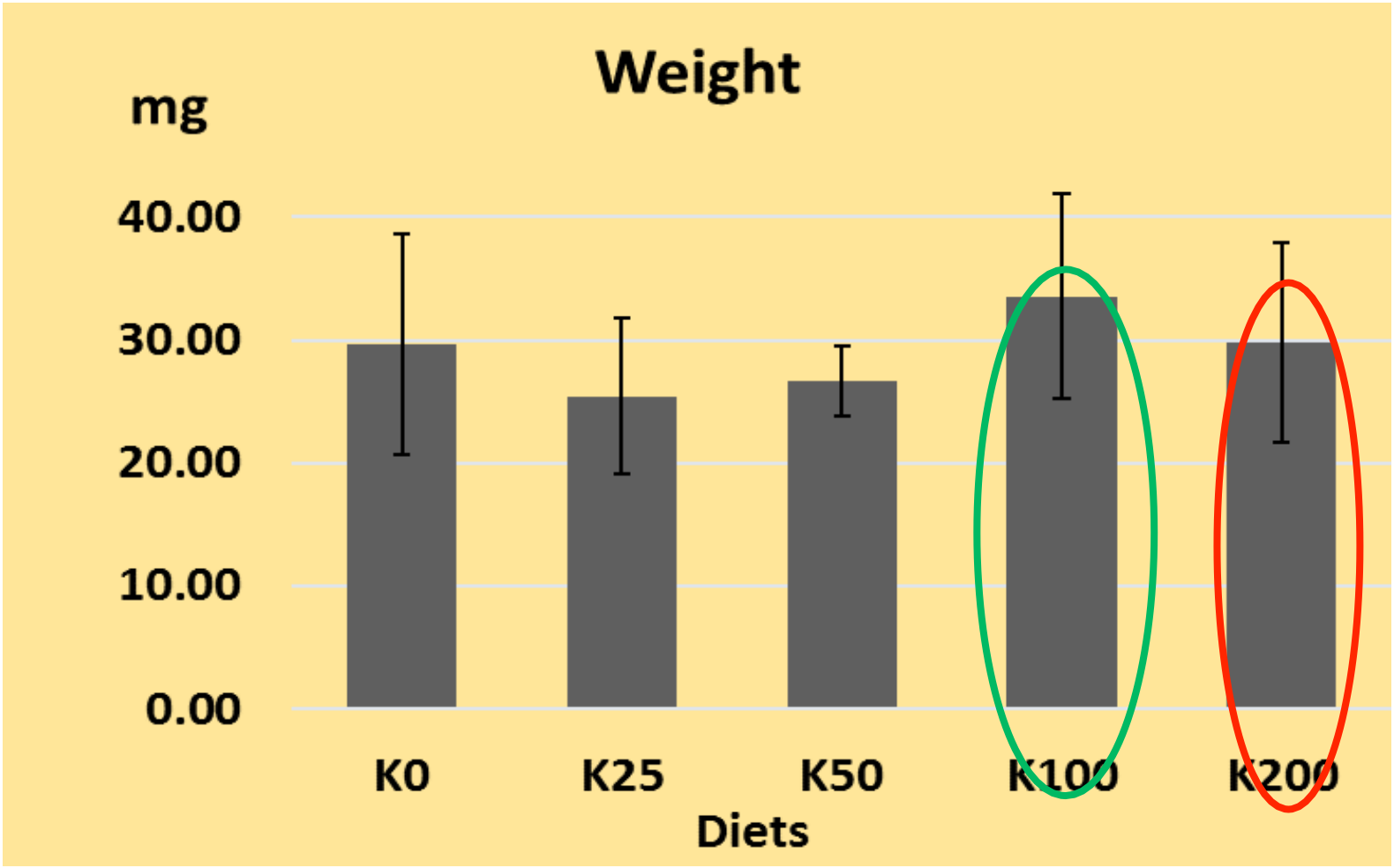
- Task 8.1. Improvement of larval weaning diets.
  3. Vitamin K



Ingredients (%)	Diets				
	K0	K25	K50	K100	K200
Squeed meal	72.9	72.9	72.9	72.9	72.9
Krill oil	10	10	10	10	10
Menadione SB (mg/kg)	0	4.32	8.64	17.28	34.56
Vit E (g/kg)	0.3	0.3	0.3	0.3	0.3
Vit C (g/kg)	0.4	0.4	0.4	0.4	0.4
Proximate composition (%)	**K0**	**K25**	**K50**	**K100**	**K200**
Proteins	72.9	68.5	70.8	66.9	68.6
Lipids	14.4	15.6	15.7	13.7	15.0
Ash	6.5	6.1	5.8	6.1	6.1
Moisture	9.9	9.3	11.3	9.6	10.5
Menadione SB (mg/kg)	1.37	1.69	3.37	5.90	14.30

- Task 8.1. Improvement of larval weaning diets.
  3. Vitamin K





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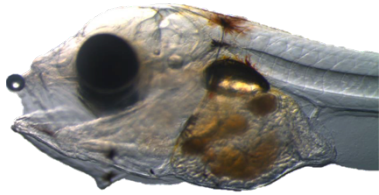

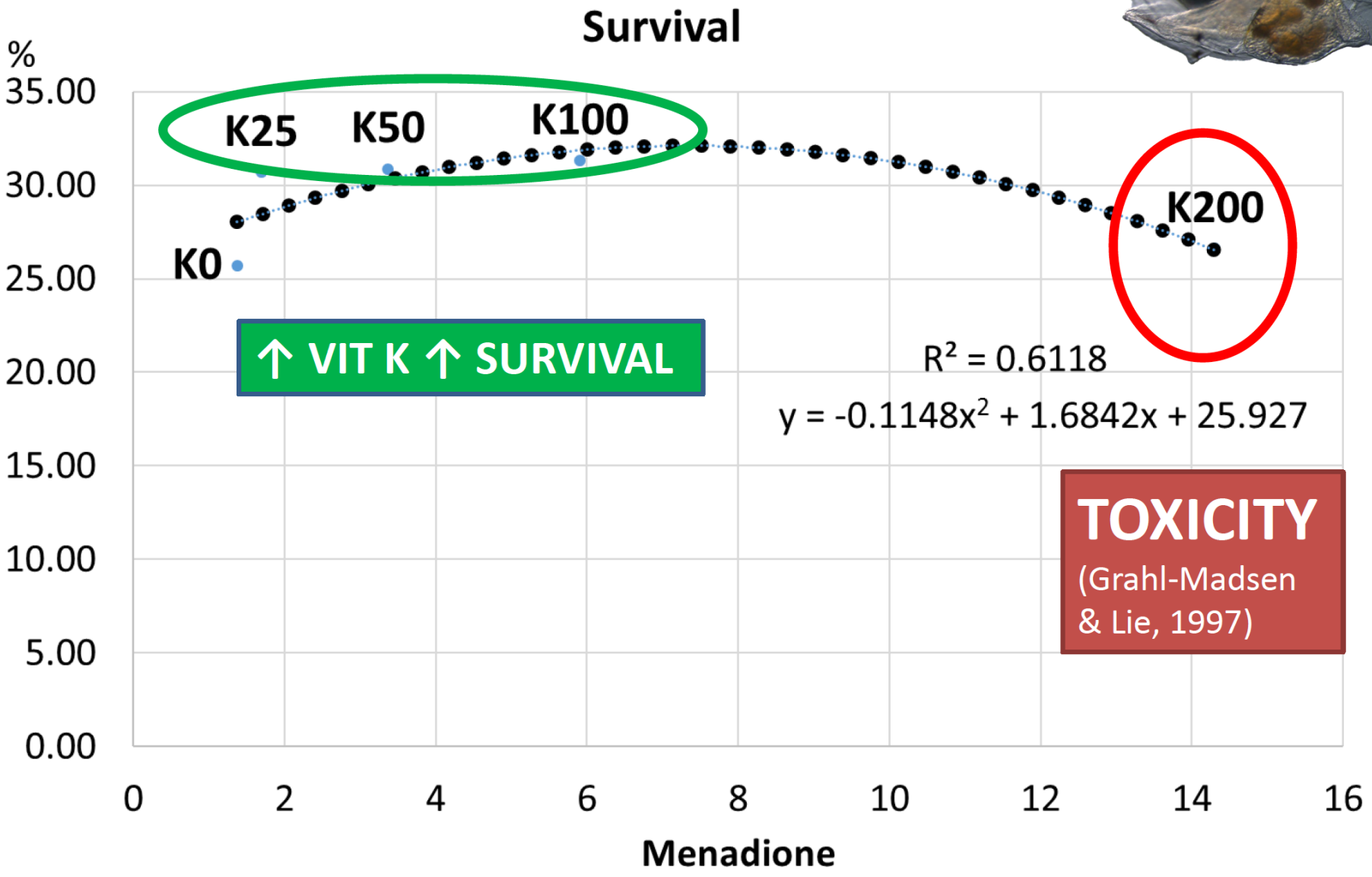

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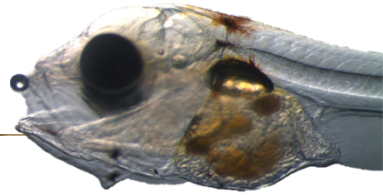

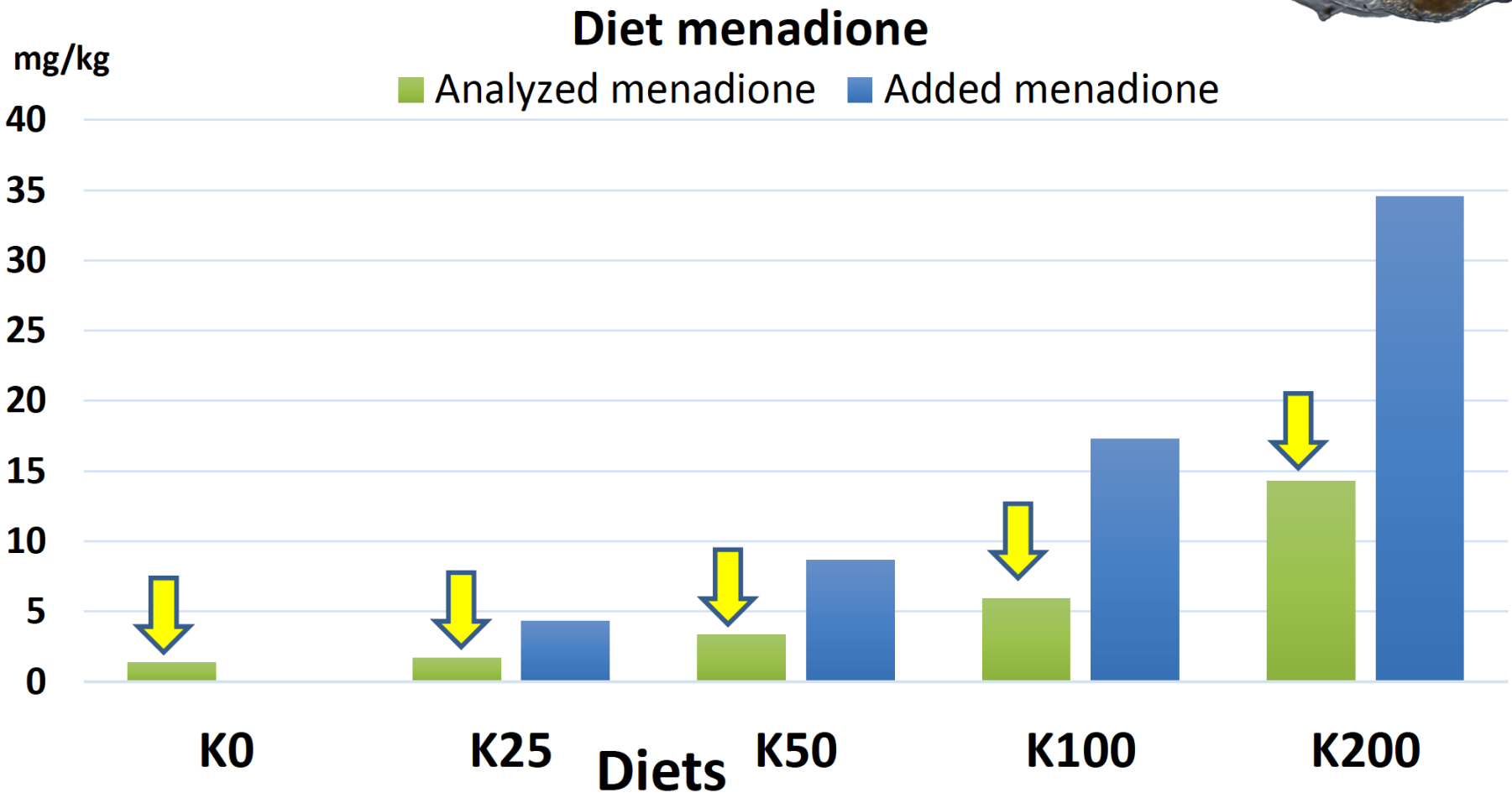

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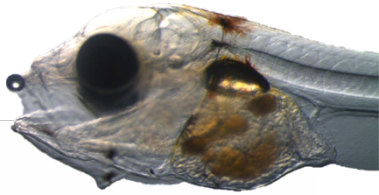
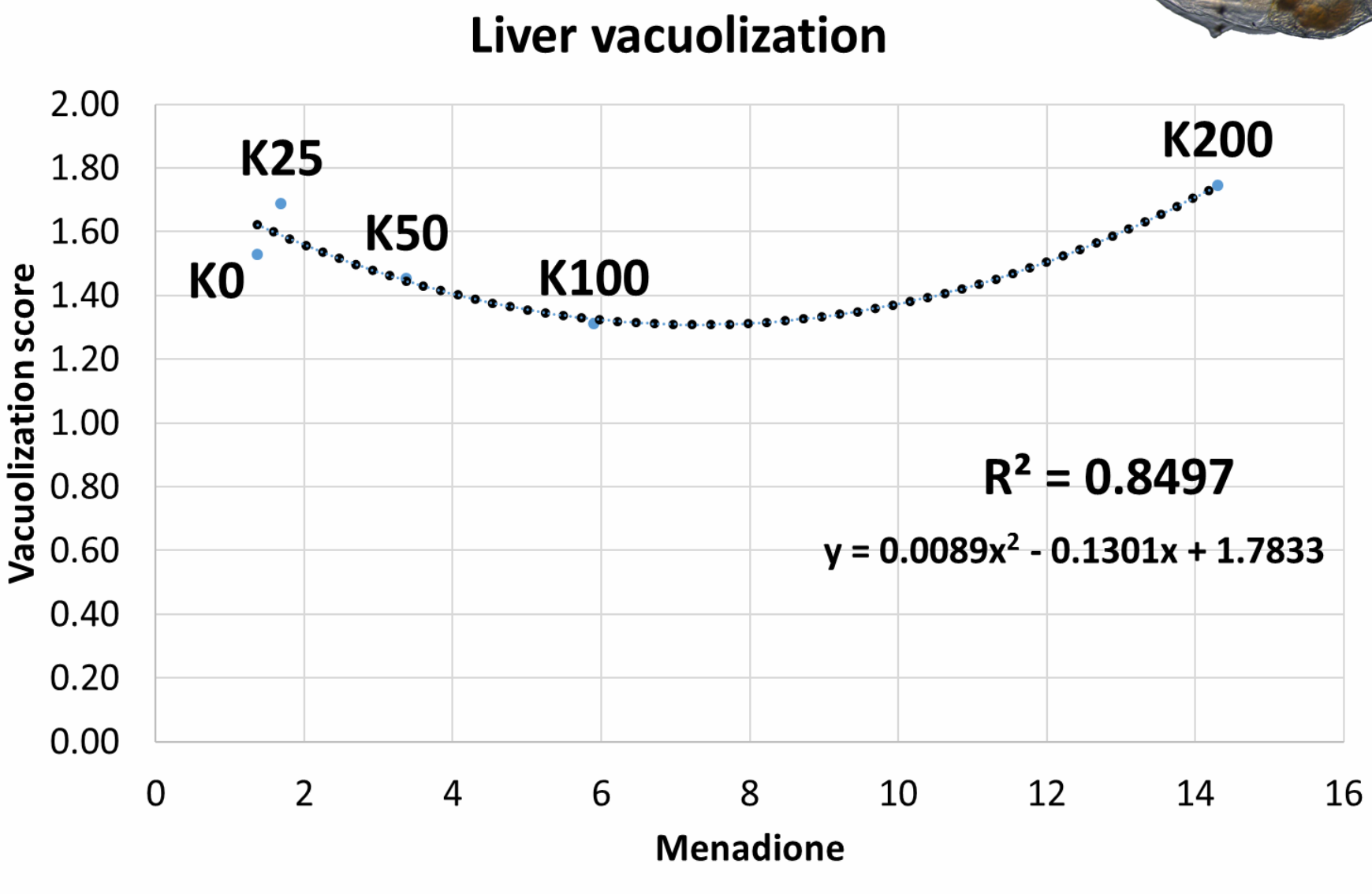
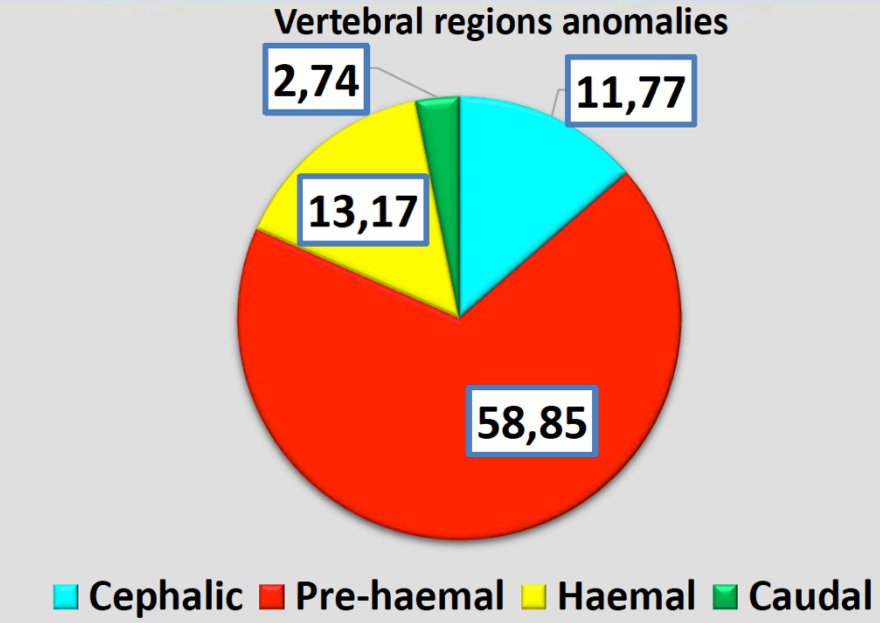
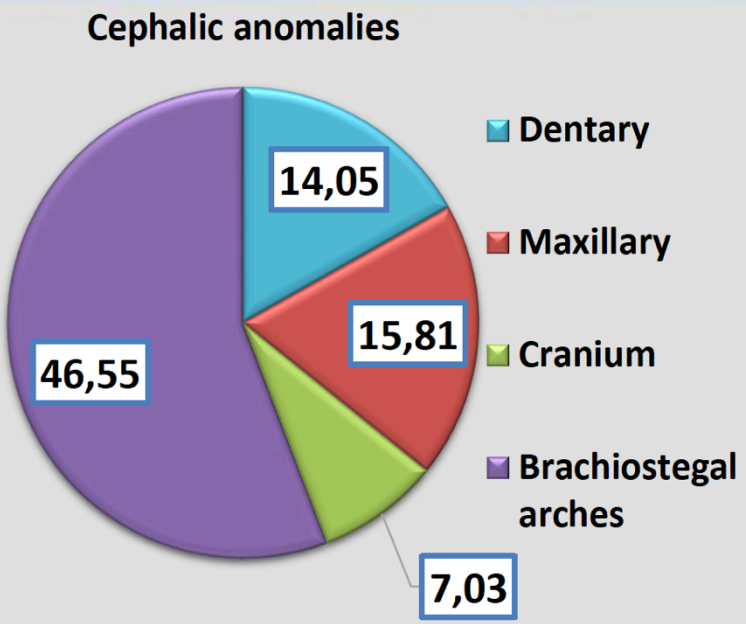


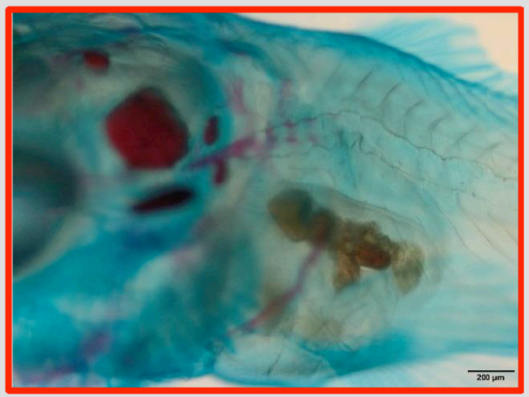


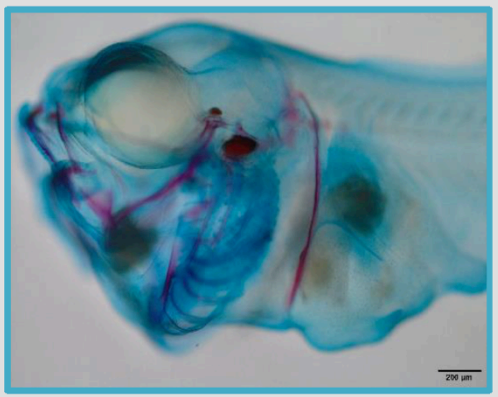
Osteology

Results & Discussion









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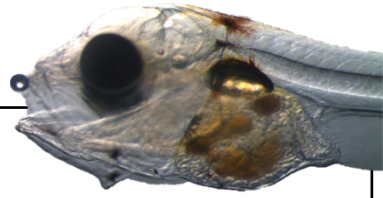
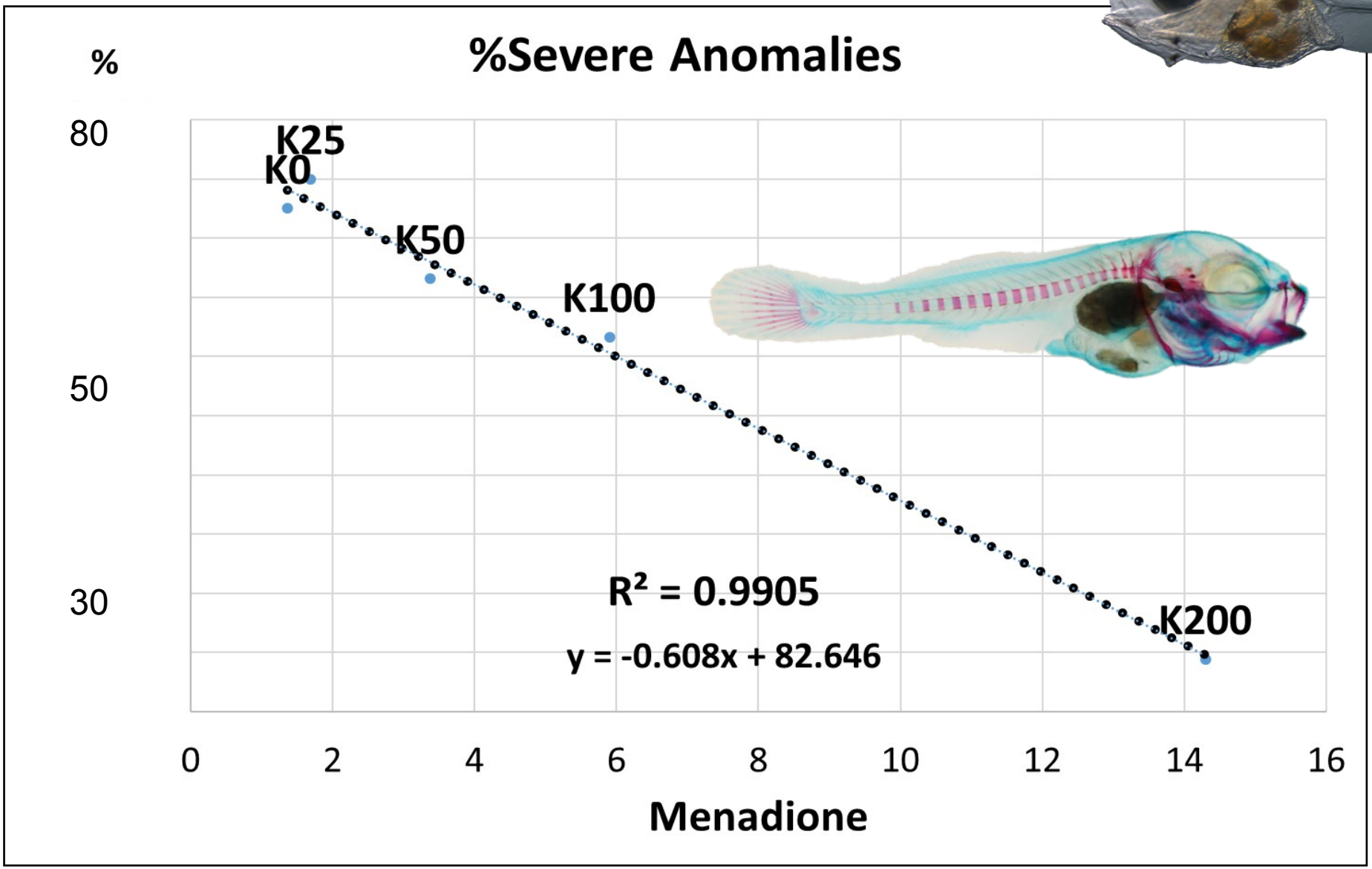
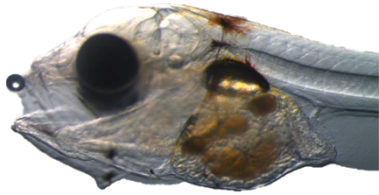
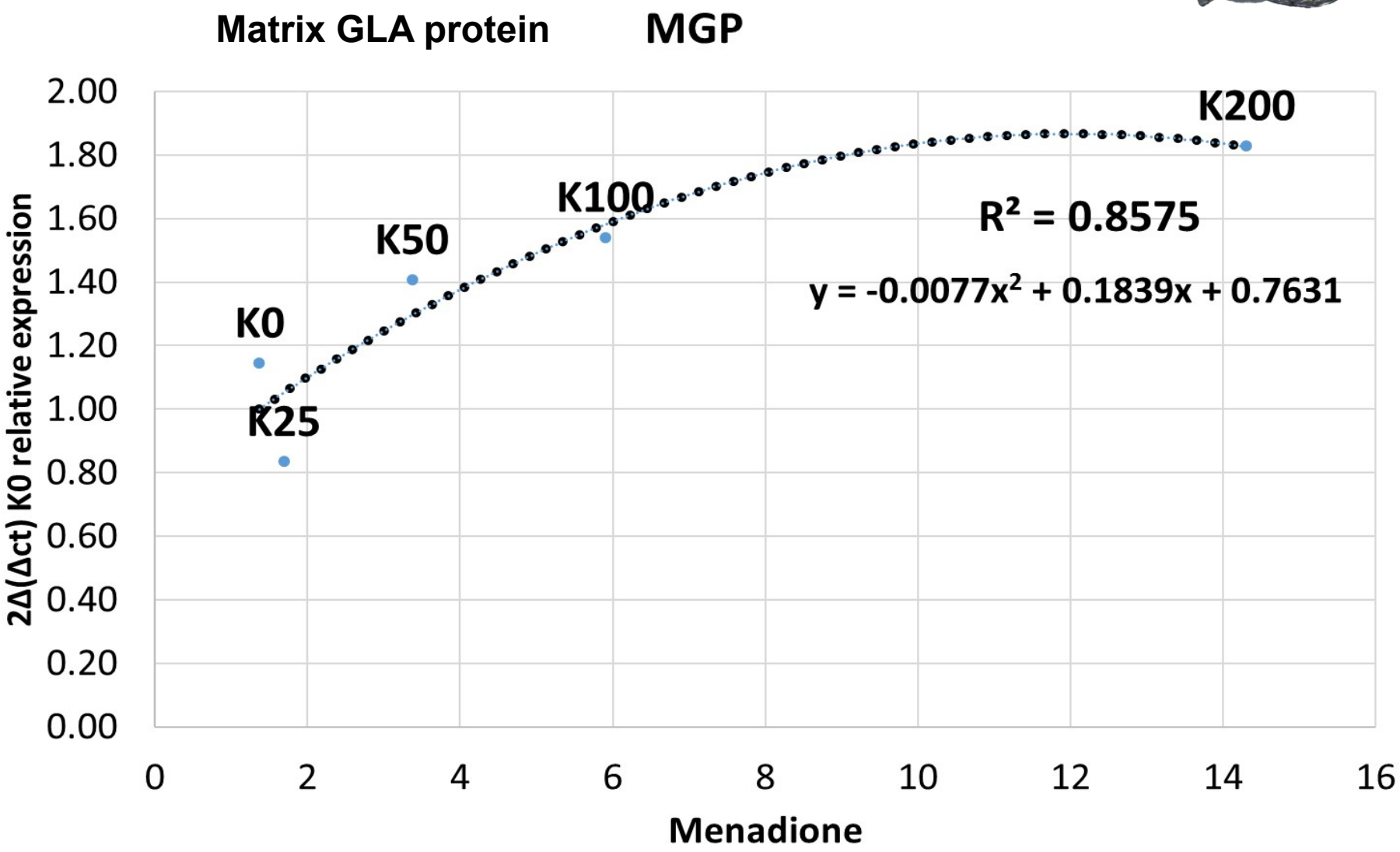
  3. Vitamin K



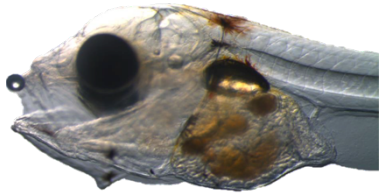


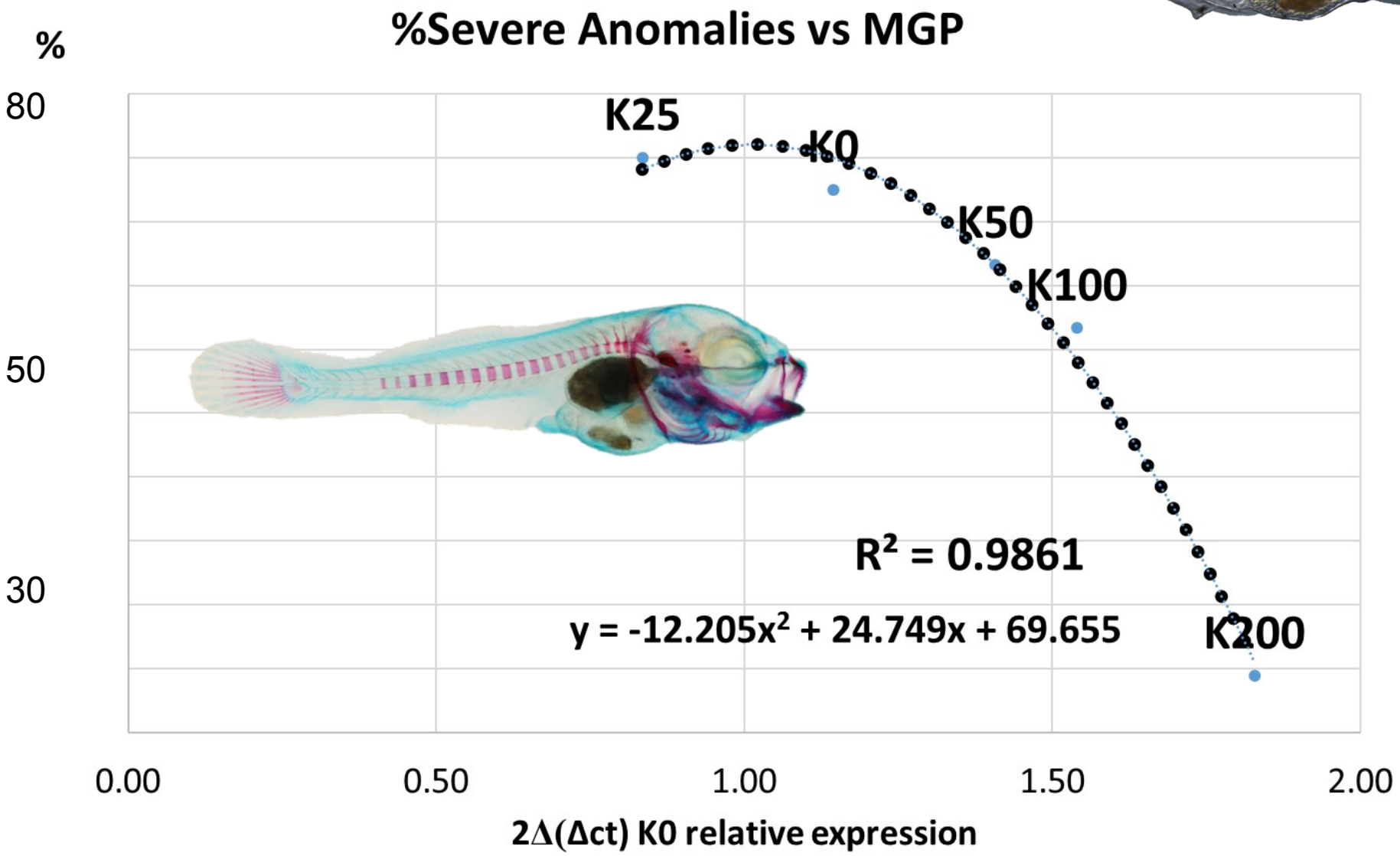
Relationship between menadione and MGP gene expression





Relationship between anomalies and MGP gene expression





- 5.90 mg/kg of menadione in diet shows a trend to increase growth and survival of meagre larvae, however, large amount seems to decrease growth and survival, possibly due to its toxic potential.

- Low levels of vitamin K may interfere in lipids utilization, increasing intestinal and hepatic steatosis.

- **5.90 mg/kg of menadione may be an adequate level for meagre larvae good performance.**

- **Task 8.2** Determination of nutritional requirements to promote feed utilization, consistent growth rates and fish welfare.

Implementation: FCPCT, SARC

Objective

- Evaluate the effect of 5 increasing dietary n-3 HUFA levels on:
  - Growth performance
  - Feed utilization
  - Whole-body composition
  - Desaturase and elongase gene expression

- Estimate the effect of vitamins for meagre fingerlings health

Methodological approach

- **Dietary treatments**

16.5% DM lipids
0.9 EPA/DHA
0.1-0.7% ARA (of total FA)
Feeding: 3x/day until apparent satiety during 30 days.

Composition (%) and proximate analysis of the experimental diets for meagre fingerlings.

	Dietary n-3 HUFA level (%DM)				
	0.8	1.4	2.0	2.6	3.6
Ingredients (%)					
Fish meal, N. Atlantic[a]	15.0	15.0	15.0	15.0	15.0
Corn gluten[b]	10.0	10.0	10.0	10.0	10.0
Faba beans[a]	10.0	10.0	10.0	10.0	10.0
Wheat[a]	8.0	8.0	8.0	8.0	8.0
Wheat gluten[a]	18.4	18.4	18.4	18.4	18.4
Soy protein concentrate[a]	25.0	25.0	25.0	25.0	25.0
Fish oil, S. American[a]	0.0	2.7	5.4	8.2	10.9
Linseed oil[c]	1.6	1.2	0.8	0.4	0.0
Palm oil[3]	3.3	2.5	1.7	0.8	0.0
Rapeseed oil[a]	6.0	4.5	3.0	1.5	0.0
Premix[d]	2.8	2.8	2.8	2.8	2.8
Proximate analysis (% DM)					
Protein	56.5	54.5	54.5	56.0	54.3
Lipids	16.2	17.0	16.5	16.9	16.2
Ash	4.9	5.0	5.1	5.2	5.0
Moisture	8.7	8.5	8.5	8.2	7.9

Methodological approach

- Rearing conditions
  - IBW: 2.8 g; IBL: 6.4 cm
  - 200 L - tanks (3 x treatment)
  - 45 fish/tank
  - Temperature: 23±0.2 ºC

- Final sampling
  - Biological parameters: body weight, lenght and feed intake
  - Biochemistry: whole-body composition and diets (protein, lipids, FA content, ash and moisture)
  - Gene expression in liver: Δ6 desaturase and Elovl5

Results- Growth performance

	Dietary n-3 HUFA level (%DM)				
	0.8	1.4	2.0	2.6	3.6
Survival (%)	93.3±0.7	97.8±1.3	99.3±0.7	94.8±1.5	97.8±2.2
Initial total length (cm)	6.4±0.0	6.3±0.1	6.3±0.0	6.4±0.0	6.2±0.0
Final total length (cm)	9.0±0.1^{c}	9.4±0.1^{b}	9.3±0.1^{ab}	9.6±0.1^{a}	9.3±0.1^{bc}
Initial body weight (g)	2.8±0.1	2.8±0.1	2.7±0.1	2.7±0.1	2.6±0.1
Final body weight (g)	9.5±0.3^{b}	10.4±0.3^{a}	10.2±0.4^{ab}	10.7±0.3^{a}	10.4±0.3^{a}
WG (g)	6.7±0.4	7.5±0.4	7.6±0.3	8.0±0.3	7.8±0.2
SGR (% day^{-1})	4.1±0.1	4.3±0.2	4.5±0.1	4.5±0.1	4.6±0.1
TGC	1.0±0.0	1.1±0.1	1.1±0.0	1.2±0.0	1.2±0.0
FI (g feed fish^{-1} day^{-1})	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0
FCR	0.8±0.1	0.7±0.0	0.7±0.0	0.7±0.0	0.7±0.0
K (%)	1.3±0.0	1.3±0.0	1.3±0.1	1.2±0.1	1.3±0.0
PER	2.4±0.2	2.6±0.1	2.5±0.1	2.6±0.1	2.6±0.1

Different letters are significantly different ($P<0.05$)

- No external signs of EFA-deficiency nor mortality
- **Higher growth rates and good feed conversion ratios**

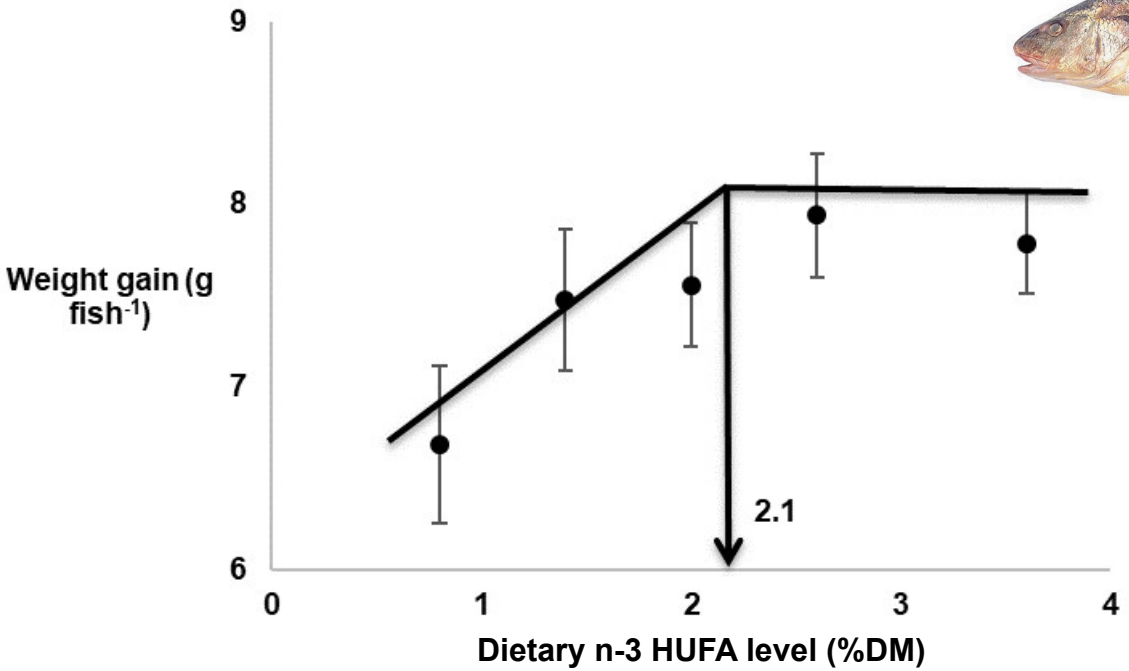
Results- Growth performance

	Dietary n-3 HUFA level (%DM)				
	0.8	1.4	2.0	2.6	3.6
Survival (%)	93.3±0.7	97.8±1.3	99.3±0.7	94.8±1.5	97.8±2.2
Initial total length (cm)	6.4±0.0	6.3±0.1	6.3±0.0	6.4±0.0	6.2±0.0
Final total length (cm)	9.0±0.1^{c}	9.4±0.1^{b}	9.3±0.1^{ab}	9.6±0.1^{a}	9.3±0.1^{bc}
Initial body weight (g)	2.8±0.1	2.8±0.1	2.7±0.1	2.7±0.1	2.6±0.1
Final body weight (g)	9.5±0.3^{b}	10.4±0.3^{a}	10.2±0.4^{ab}	10.7±0.3^{a}	10.4±0.3^{a}
WG (g)	6.7±0.4	7.5±0.4	7.6±0.3	8.0±0.3	7.8±0.2
SGR (% day^{-1})	4.1±0.1	4.3±0.2	4.5±0.1	4.5±0.1	4.6±0.1
TGC	1.0±0.0	1.1±0.1	1.1±0.0	1.2±0.0	1.2±0.0
FI (g feed fish^{-1} day^{-1})	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0
FCR	0.8±0.1	0.7±0.0	0.7±0.0	0.7±0.0	0.7±0.0
K (%)	1.3±0.0	1.3±0.0	1.3±0.1	1.2±0.1	1.3±0.0
PER	2.4±0.2	2.6±0.1	2.5±0.1	2.6±0.1	2.6±0.1

Different letters are significantly different ($P<0.05$)

Dietary n-3 HUFA increase was **significantly correlated** to final body weight ($P=0.09$, $r^2=0.82$), WG ($P=0.05$, $r^2=0.86$), SGR ($P=0.01$, $r^2=0.94$) and TGC ($P=0.01$, $r^2=0.94$).

Results- Growth performance



Requirement: **2.1%** n-3 HUFA

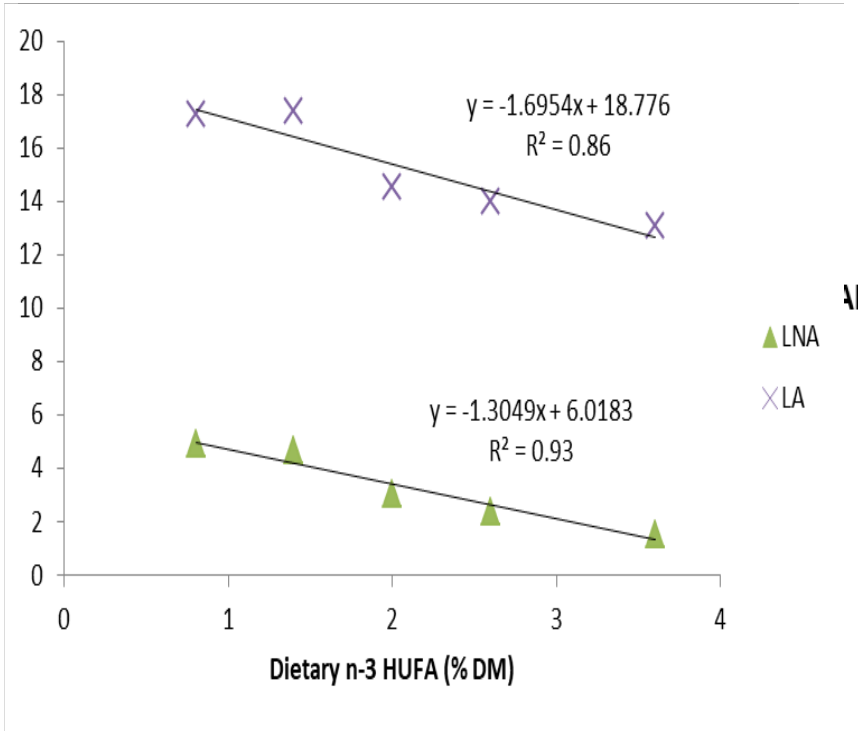
Similar to what found for red seabream (Takeuchi et al., 1992a) and yellowtail (Takeuchi et al., 1992b) , but higher than red drum (Lochman and Gatlin, 1993), seabream (Ibeas et al., 1996) and seabass (Skalli and Robin, 2004).

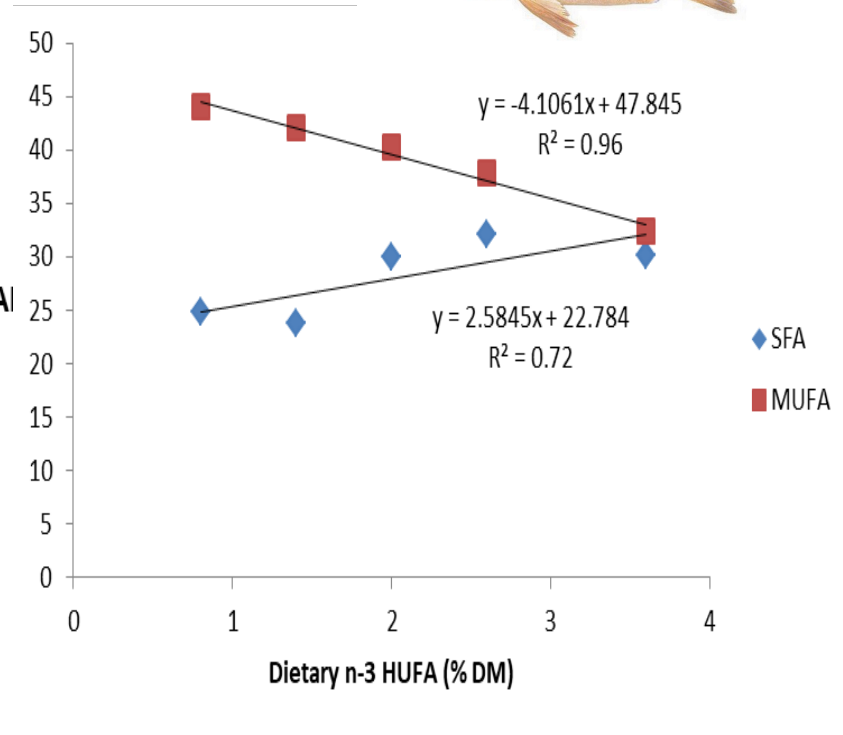
Results- Body composition (% wet weight)

	Dietary n-3 HUFA level (% DM)					
	Initial	0.8	1.4	2.0	2.6	3.6
Protein	15.6±0.49	15.8±0.17	16.1±0.12	15.6±0.28	16.3±0.50	16.0±0.61
Lipid	2.2±0.12	4.1±0.47	4.1±0.25	3.8±0.24	3.8±0.28	3.9±0.25
Ash	3.9±0.26	2.7±0.22	2.7±0.09	2.8±0.14	2.8±0.04	2.6±0.29
Moisture	78.6±0.28	78.1±0.82	77.7±0.03	78.0±0.60	78.5±0.13	78.7±0.20

No significant differences observed between fish fed different treatments.

Results- Whole-body FA content





Reflecting diet composition

According to the increase substitution of VO by FO

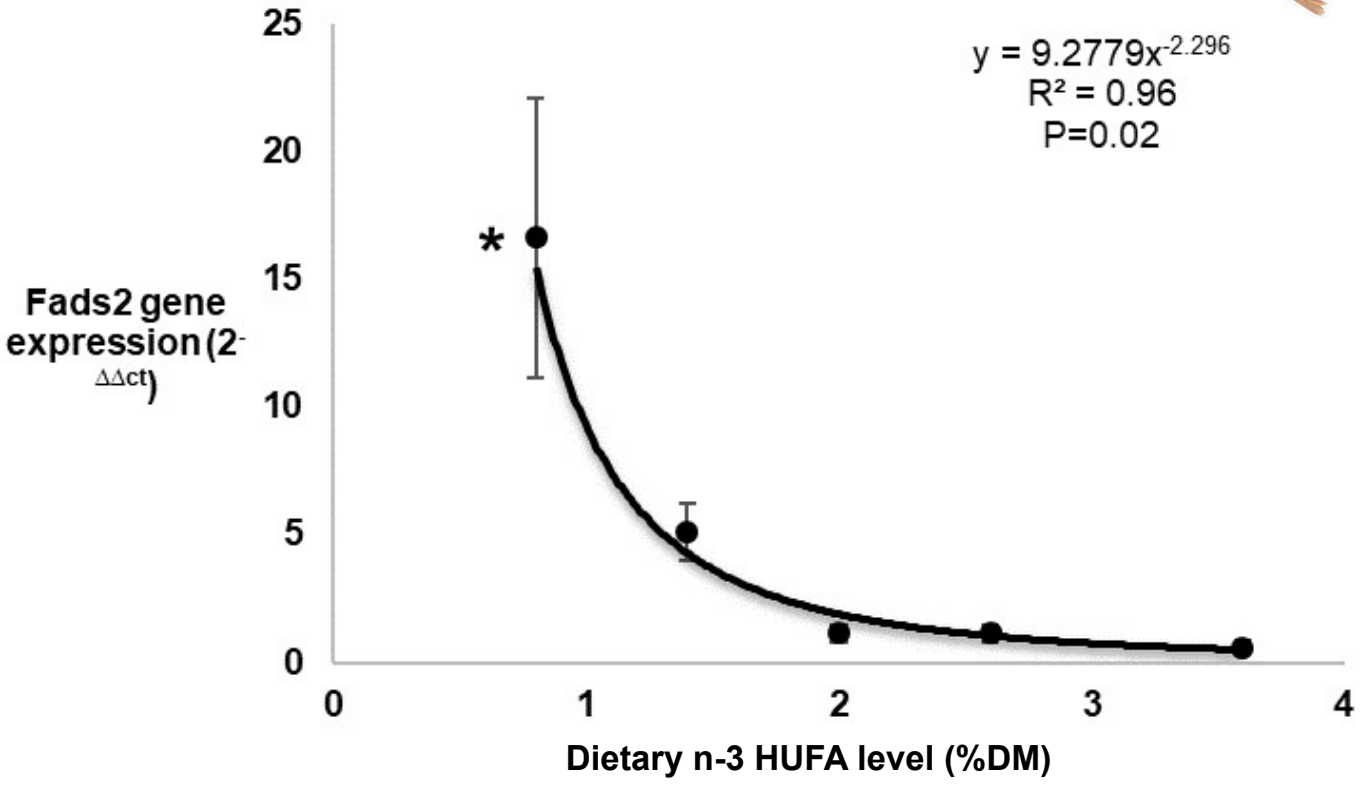
Results- FA rentention efficiency (% FA intake)

Fatty acid	Dietary n-3 HUFA level (% DM)				
	0.8	1.4	2.0	2.6	3.6
18:2n-9	251.9±43.0^{a}	125.7±16.5^{b}	55.1±16.2^{b}	47.2±1.2^{b}	37.7±1.4^{b}
18:3n-6	190.8±44.8	107.8±14.7	48.2±13.7	40.9±2.4	65.5±12.6
18:4n-3	23.3±3.6	26.9±4.7	14.6±4.3	18.9±3.3	30.0±3.2
18:3n-3	25.7±5.3^{b}	38.7±4.1^{ab}	24.5±4.3^{b}	31.7±2.9^{b}	56.8±5.2^{a}
20:3n-3	315.0±88.6^{a}	256.1±24.6^{ab}	136.6±12.9^{abc}	50.8±0.6^{b}	68.2±10.7^{b}
20:2n-6	227.8±57.4^{a}	165.4±11.4^{ab}	114.2±12.8^{ab}	82.2±110.7^{b}	86.5±10.3^{ab}
20:4n-6	55.0±18.2	57.2±2.8	28.7±8.9	32.9±3.0	53.1±6.7
20:5n-3	25.0±6.7	31.3±4.4	13.3±4.7	17.9±4.1	30.3±4.3
22:6n-3	56.1±5.8^{a}	41.4±3.^{b}	41.5±4.7^{b}	37.5±0.7^{b}	39.9±3.7^{b}

Δ6 desaturase product

Elovl5 product

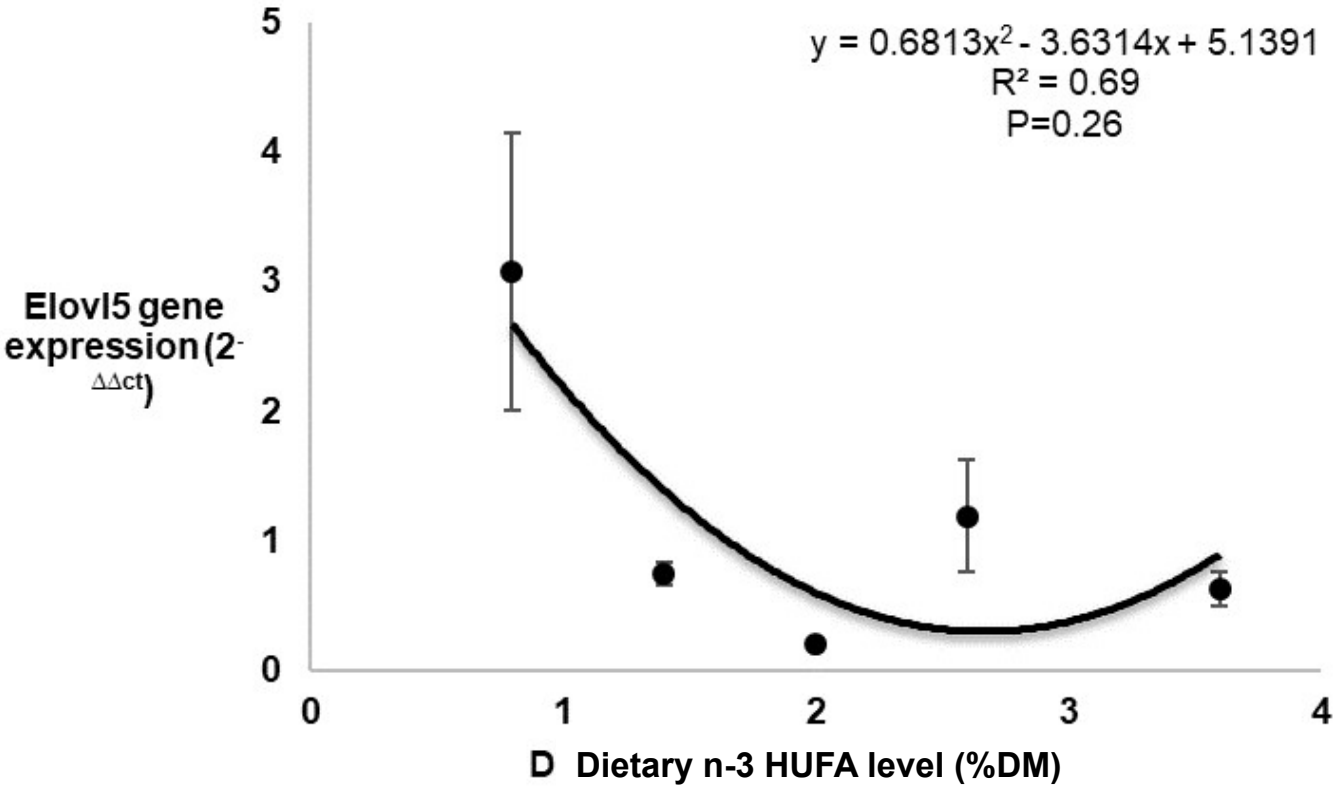
Results- Gene expression



* indicates significance difference (P=0.04) compared to diet 3.6% n-3 HUFA

Similar results found by Monroing et al., 2013

Results- Gene expression



Similar results found by Monroing et al., 2013

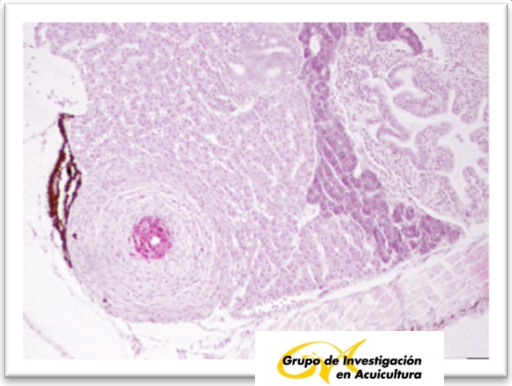
- ✓ Meagre showed the ability to selectively conserve key FA, particularly DHA and ARA over other FA, in response to EFA-deficiency.
- ✓ Meagre seems to have active Δ6 desaturase and Elovl5, but their activities being insufficient to produce enough DHA and EPA from PUFA precursors to sustain fast growth.
- ✓ Meagre fingerlings have n-3 HUFA requirement around 2.1% DM in diets containing 16.5% DM lipids, 0.9 EPA/DHA and 0.4% ARA of total FA contents.

Dietary combinations of vitamin E, C and K affect the incidence of systemic granulomatosis in on-growing meagre (*Argyrosomus regius*)

Grupo de Investigación en Acuicultura

Systemic granulomatosis in Canary Islands meagre

Fish Farm – sea cage



First record of granulomas in meagre larvae

↓ vitamin C in feeds

High incidence in meagre broodstock (F1>) and juveniles

> Low vitamin K levels in weaning diets (D 8.1)

Objective

- To evaluate the effect of vitamins E and C and K on granulomatosis occurrence in meagre (*Argyrosomus regius*)

WP 24. Meagre health

Experimental design

Initial weight	79.6 ± 0.3 g
Initial density (50 fish/ tank)	7.9 kg/m^3
Tank volume	0.5 m^3
Water temperature	17.6 to 21.6 °C
Feeding period	90 days

	Diets					
Ingredients	**O**	**K**	**EC**	**KEC**	**EECC**	**KEECC**
Lutavit E-50	0.0	0.0	300.0	300.0	700.0	700.0
Lutavit C Aquastab 35%	0.0	0.0	100.0	100.0	600.0	600.0
Vitamin K	**0.0**	**35.0**	**0.0**	**35.0**	**0.0**	**35.0**
Proximate Composition						
Crude Protein (%dw)	48.8 ± 0.1	49.6 ± 0.1	48.7 ± 0.2	48.6 ± 0.1	48.7 ± 0.3	48.5 ± 0.3
Crude Lipid (%dw)	17.9 ± 0.2	17.6 ± 0.1	19.5 ± 0.4	17.4 ± 0.3	17.7 ± 0.1	16.8 ± 0.2
Vitamin E (mg/kg)	**158.7**	**172.5**	**283.6**	**276.5**	**416.4**	**449.2**
Vitamin C (mg/kg)	**16.6**	**19.0**	**71.1**	**72.4**	**227**	**240**

Growth performance

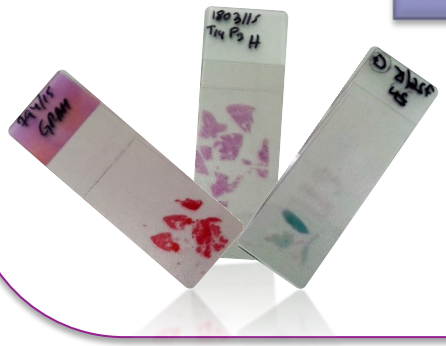
Weight, length, weight gain, K, FCR and SGR calculated at 45 and 90 days of feeding

Histology

Samples of liver, kidney, heart and spleen

- **50 initial fish**
- **23 fish / diet at 90 days**

Kidney, heart and spleen were completely processed, liver was cut in several sections (5-6) to evaluate the largest tissue-surface possible.



Hematoxylin and Eosin

Ziel-Neelsen (ZN)

Fite-Faraco method

Gram stain

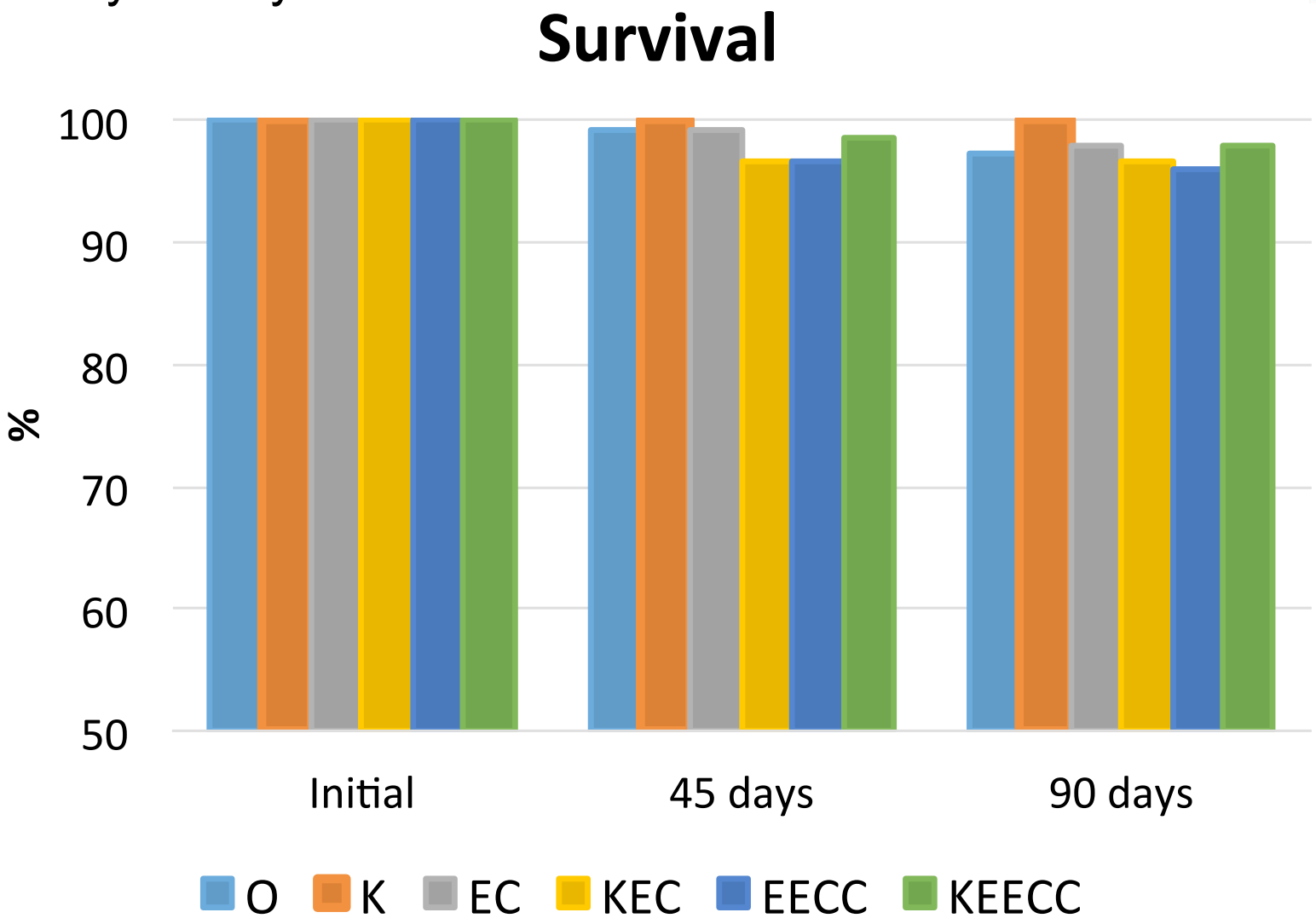
Analysis Nocardia culture

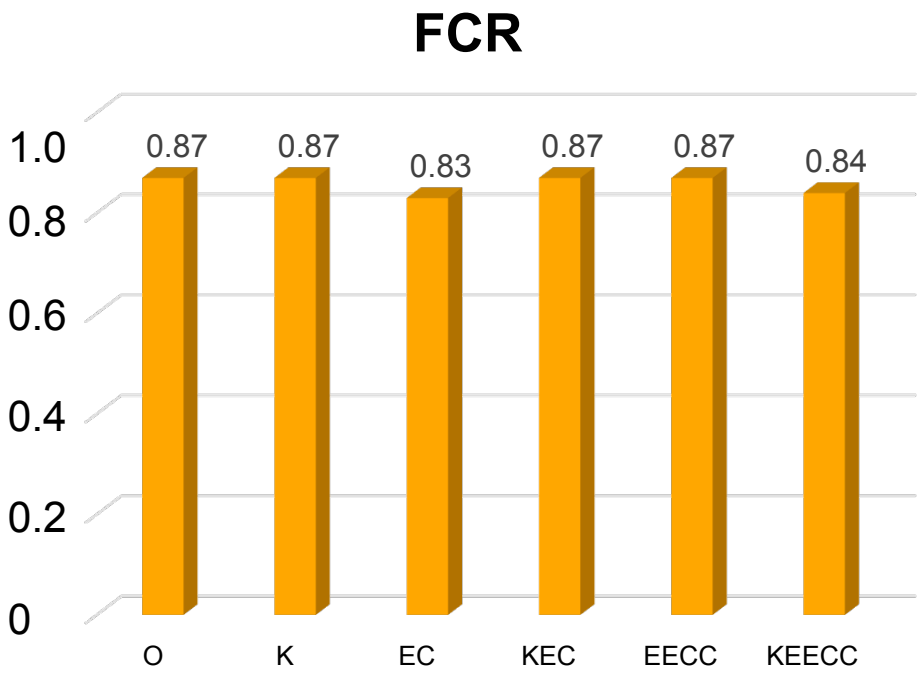
Samples of liver, kidney, heart and spleen

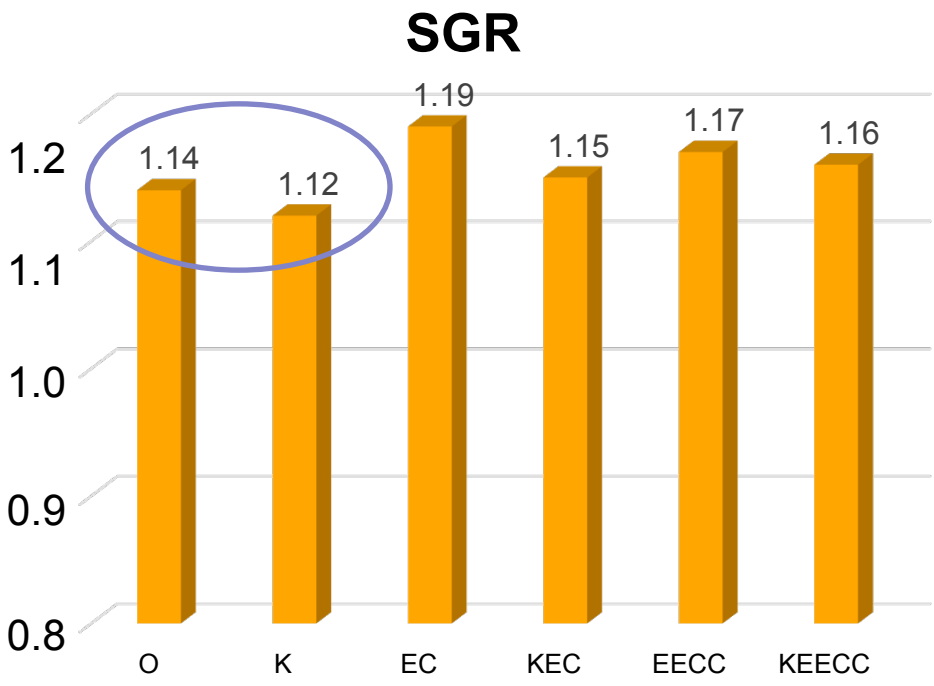
Culture medium: YEME

Gram Stain

Survival was high (96-100 %) and no significantly affected by dietary vitamin levels

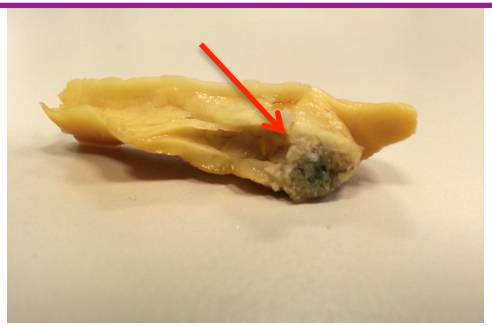




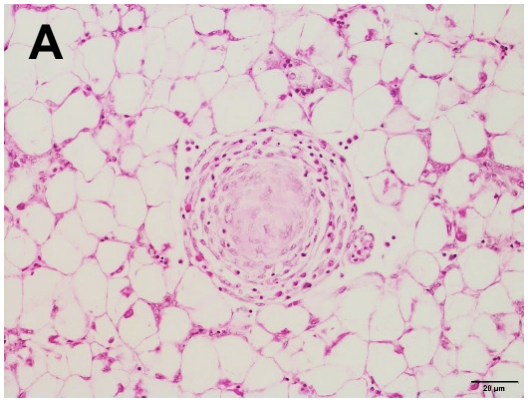


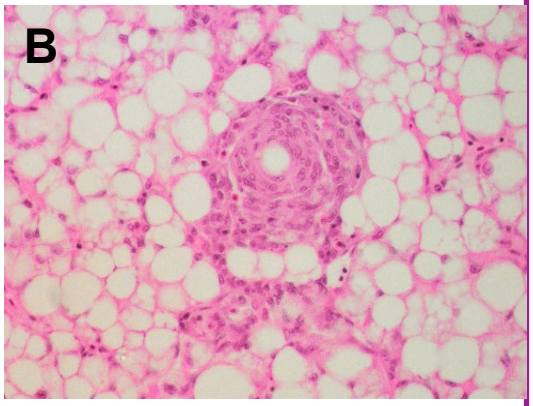
Growth was lower in meagre fed the lowest Vit E+Vit C levels

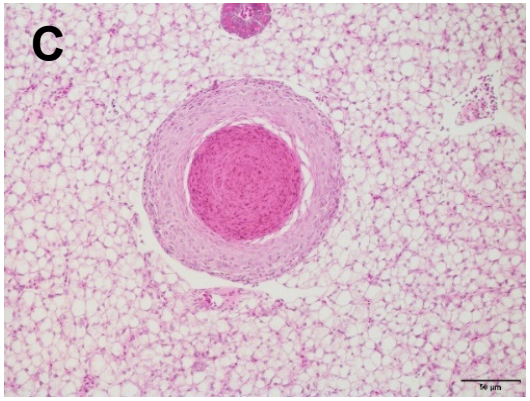
Macroscopic lesions in heart and liver only observed in 10 fish

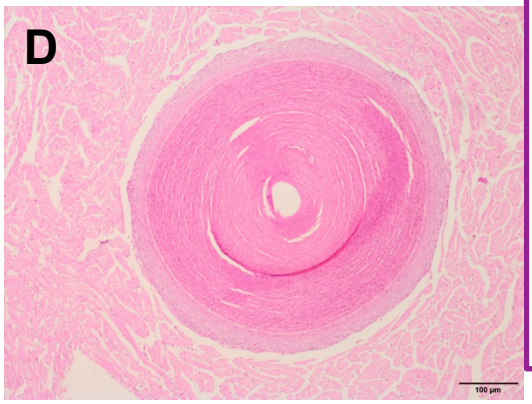


Macroscopic and histological description









(A & B) Concentric layers of macrophages and inflammatory cells around vascular endotelial cells

(C) Necrotic center with external fibroblast layer and inflammatory cells

(D) Granuloma composed completely of laminar material

No calcification was observed in any of the granulomas studied

- ✓ None of the specific stains revealed the presence of bacteria
- ✓ Nocardia culture was negative
- ✓ PCR negative to Nocardia performed in paraffin samples

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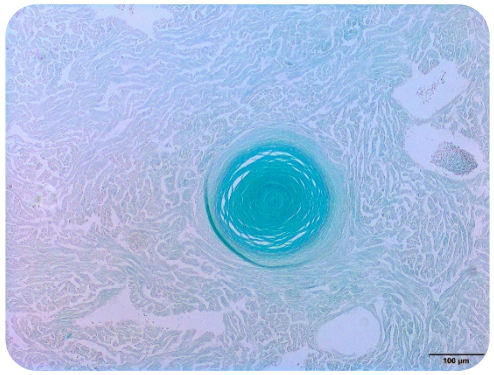
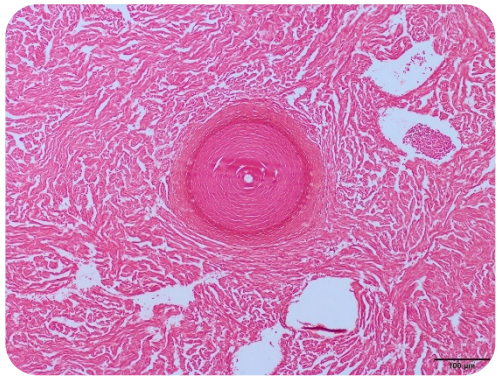
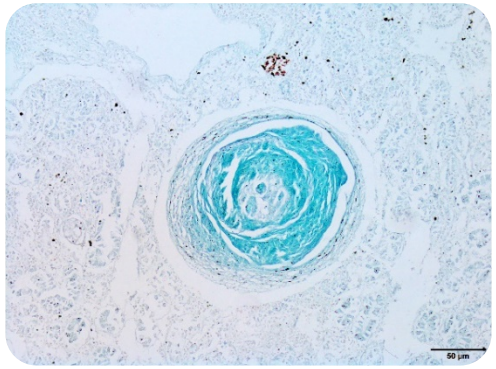
Zielh-Neelsen / Fite-Faraco / Gram stain

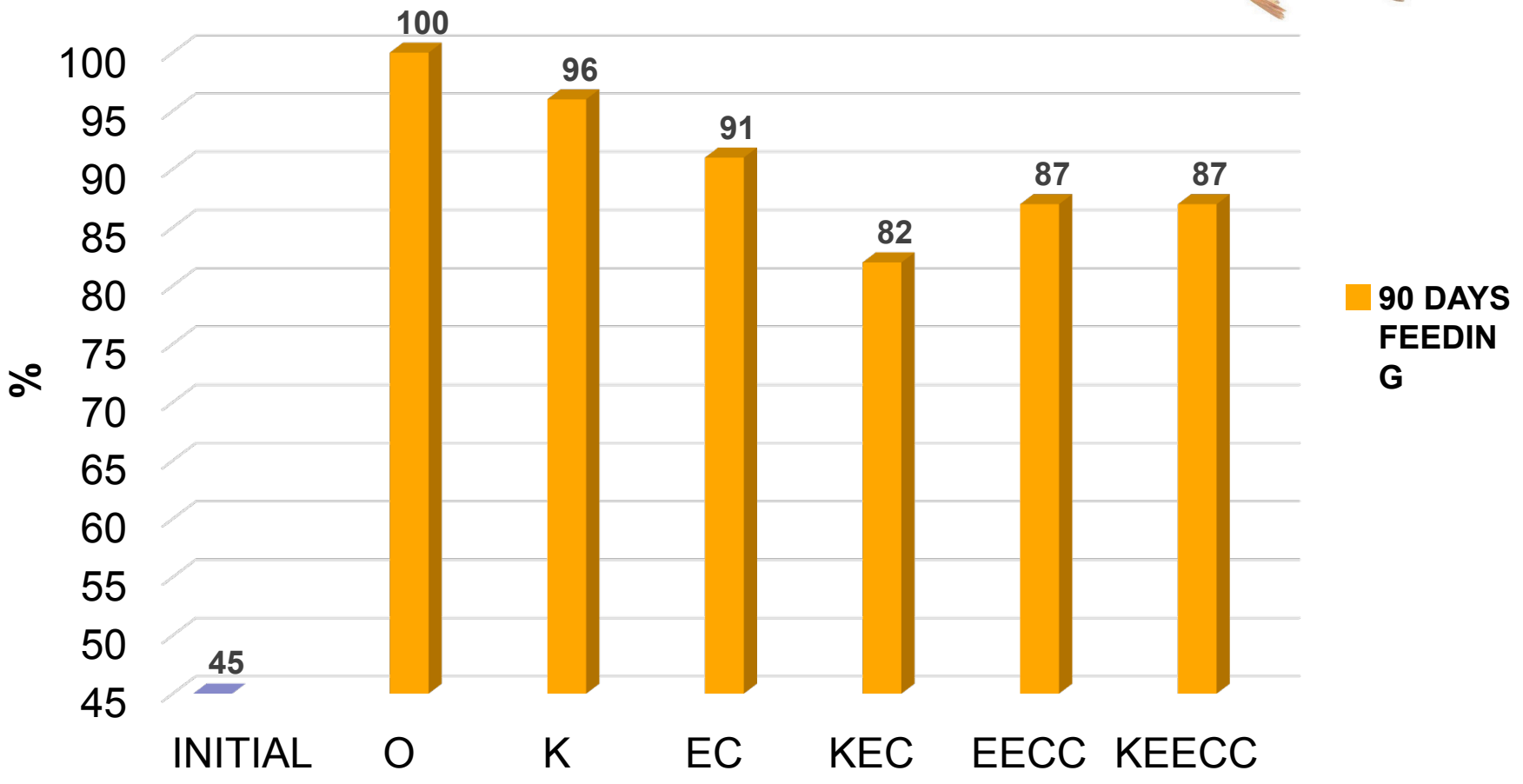




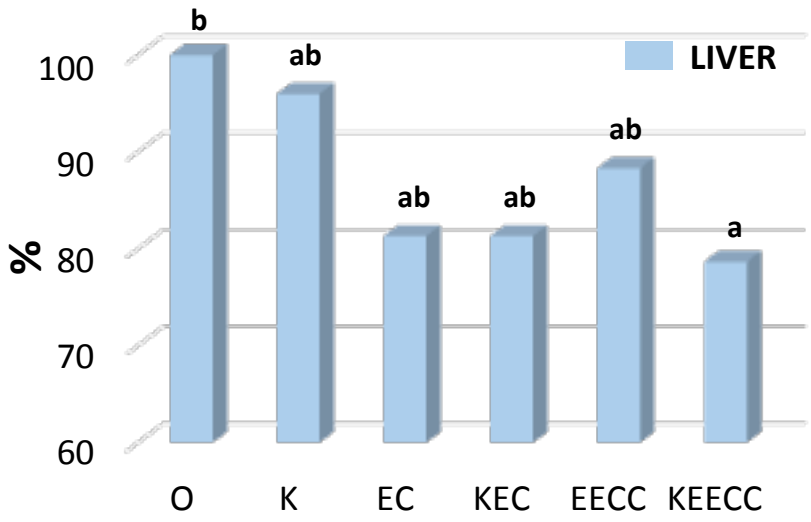


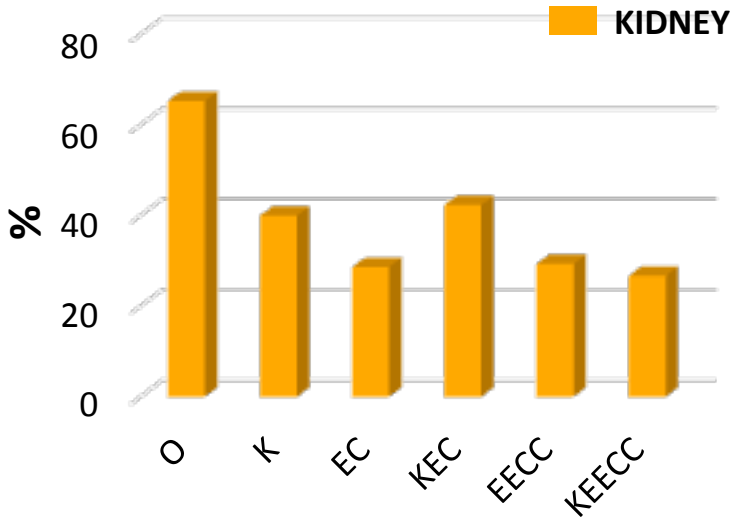
Negative results in Ziel-Neelsen, Fite-Faraco, Gram stain, bacterial cultures and PCR reinforce the non infectious character of the systemic granulomatosis in meagre (As was seen in larvae).

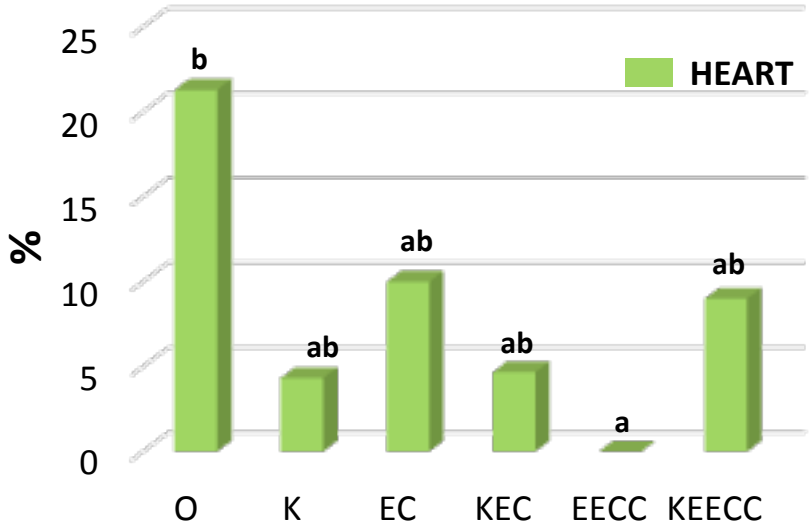
Effects of diets on granulomatosis



Effects of diets on granulomatosis incidence





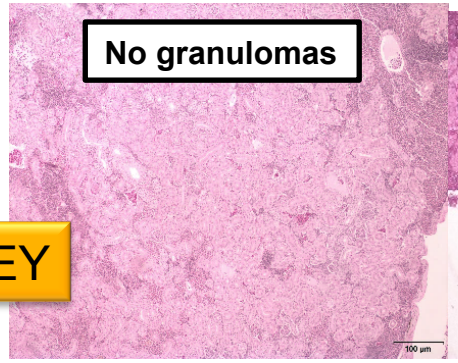
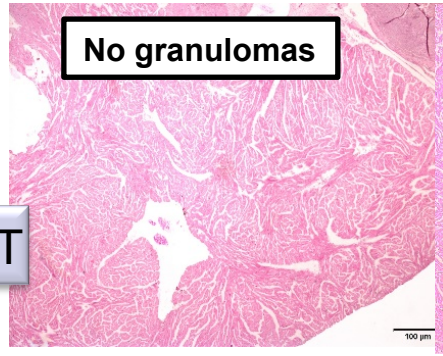


% FISH WITH GRANULOMAS IN DIFFERENT TISSUES

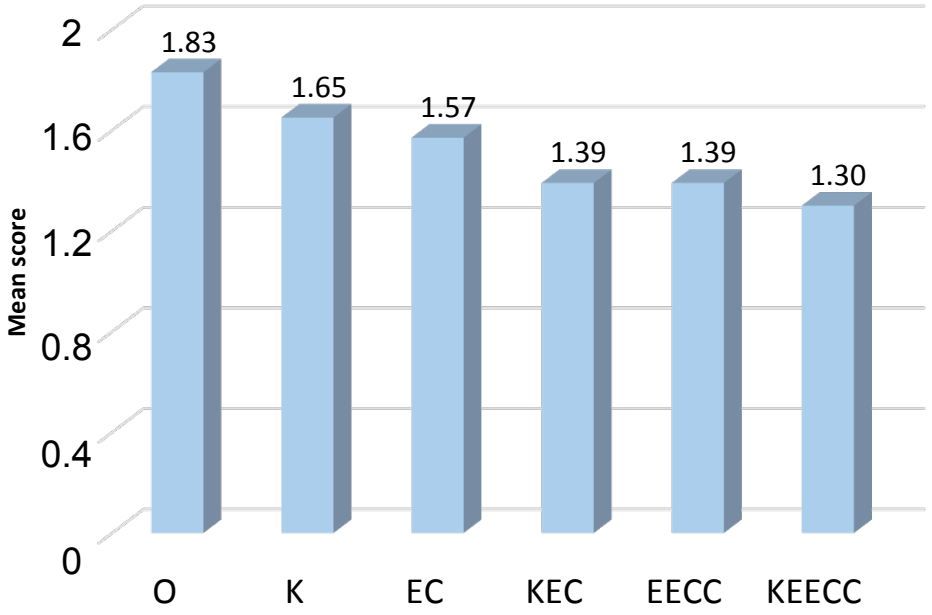
Liver > kidney > heart

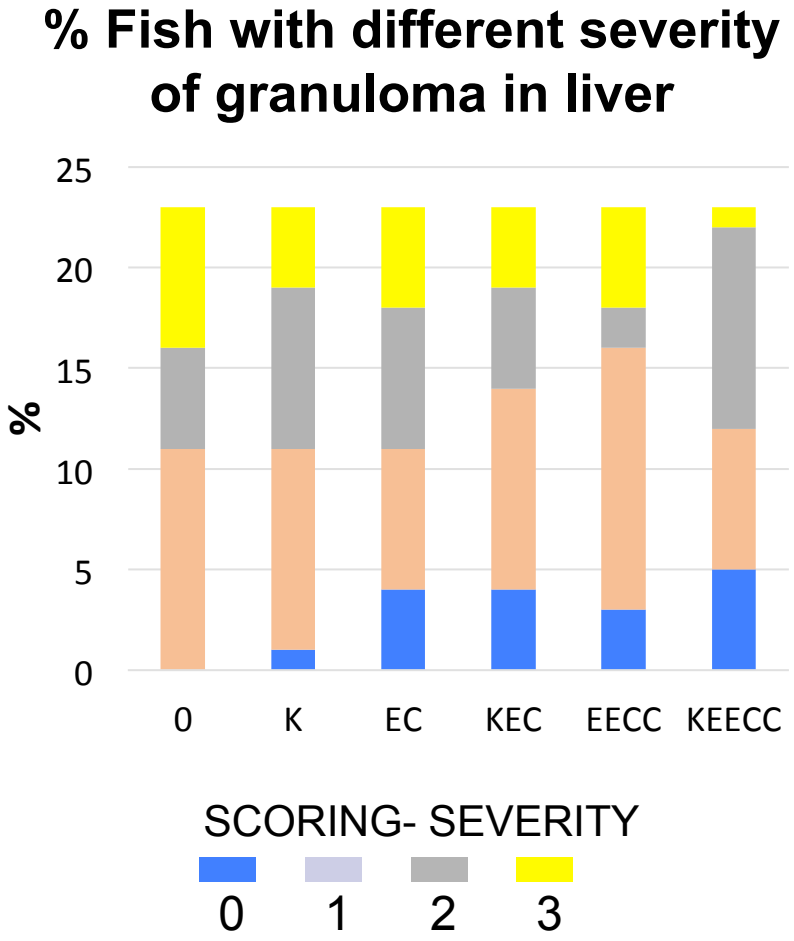
Spleen was not affected

Score - granuloma severity

	0	1	2	3
LIVER	  No granulomas	≤ 10 granulomas	10 ≤ 30 granulomas	> 30 granulomas
KIDNEY	  No granulomas	≤ 3 granulomas	4 ≤ 6 granulomas	> 6 granulomas
HEART	  No granulomas	≤ 1 granulomas	2 ≤ 2 granulomas	> 2 granulomas

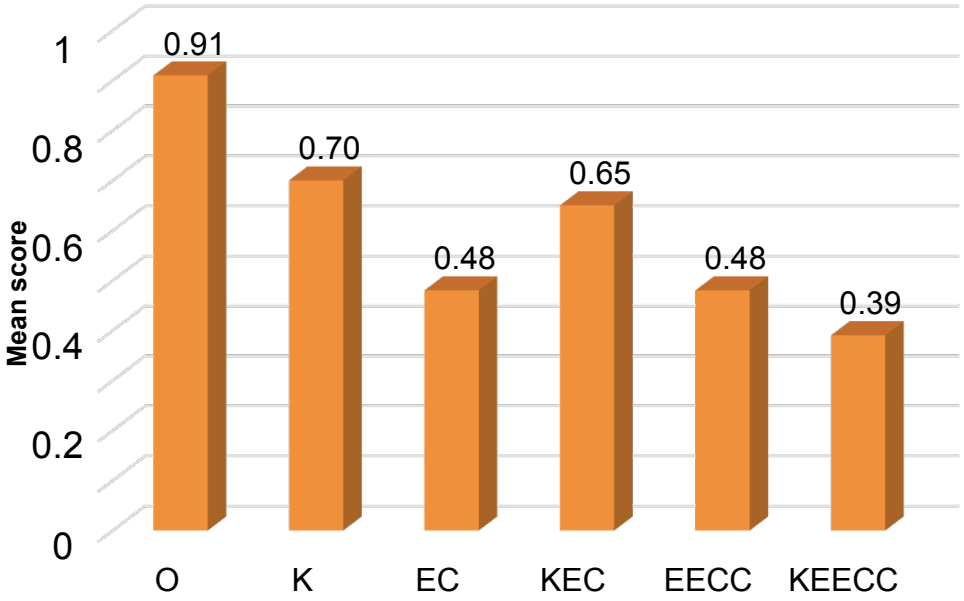
Effects of diets on granulomatosis severity



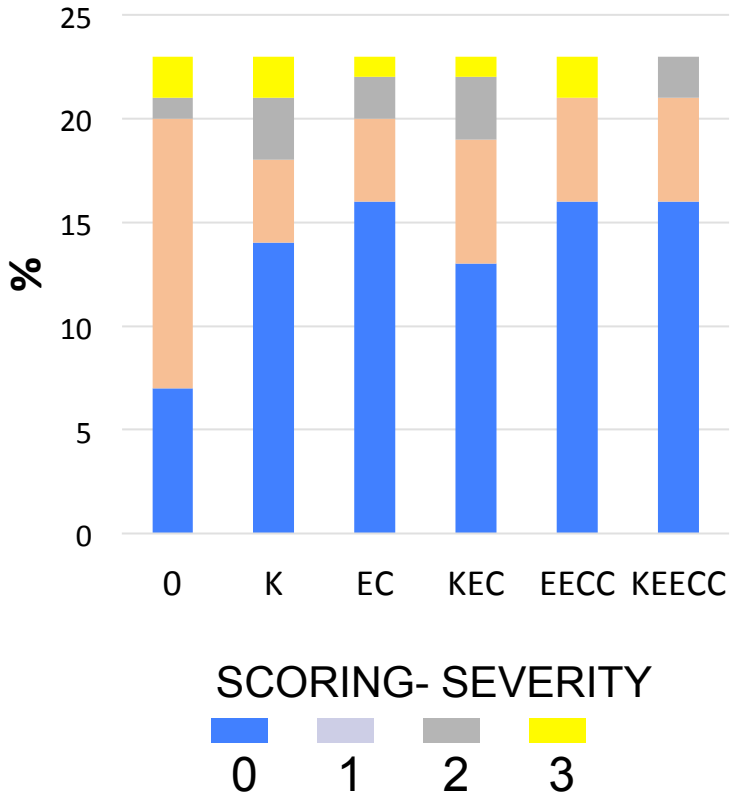


Effects of diets on granulomatosis severity

Granuloma severity in kidney

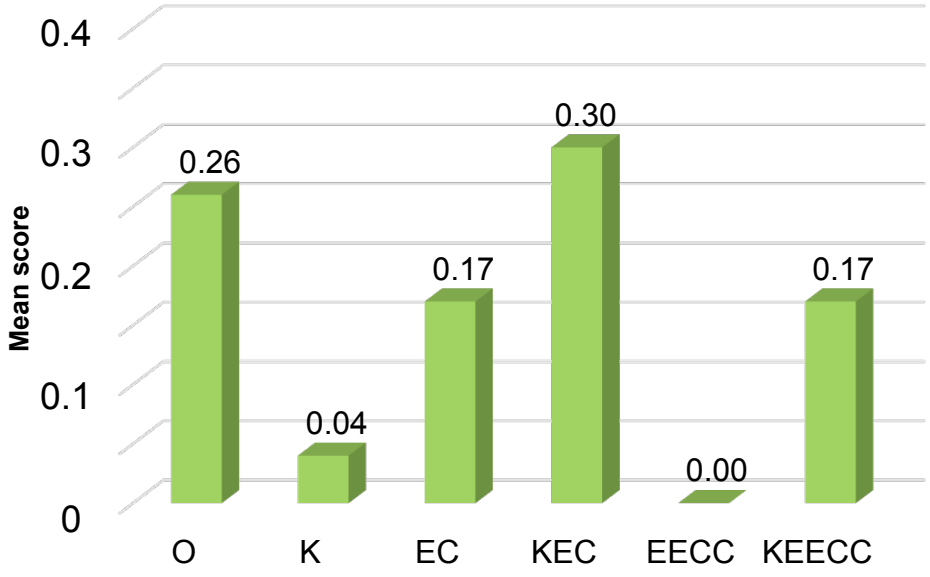


% Fish with different severity of granuloma in kidney

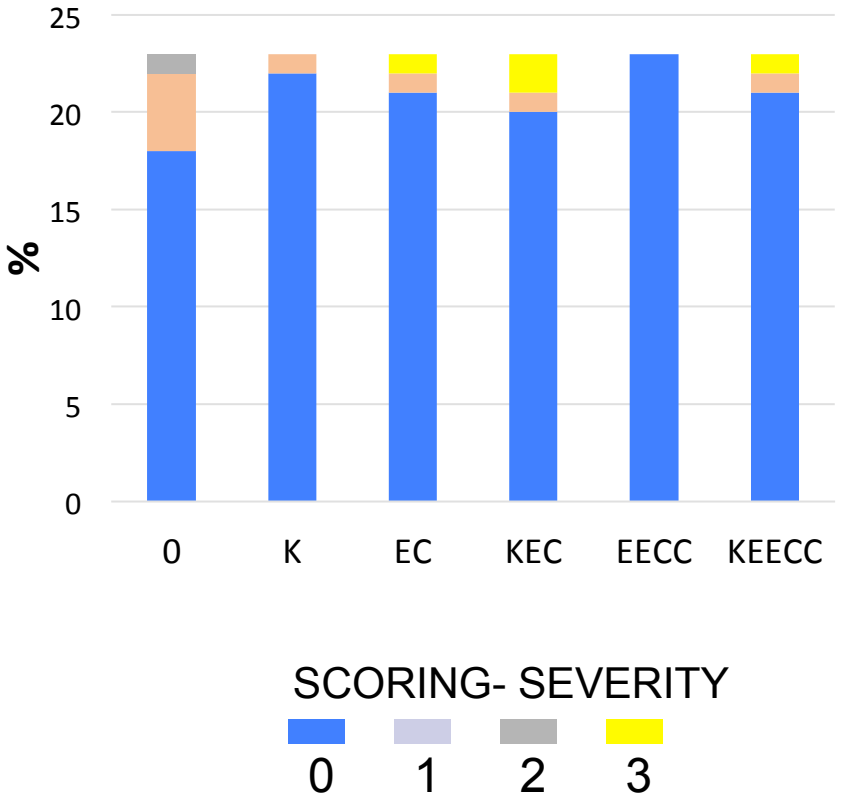


Effects of diets on granulomatosis

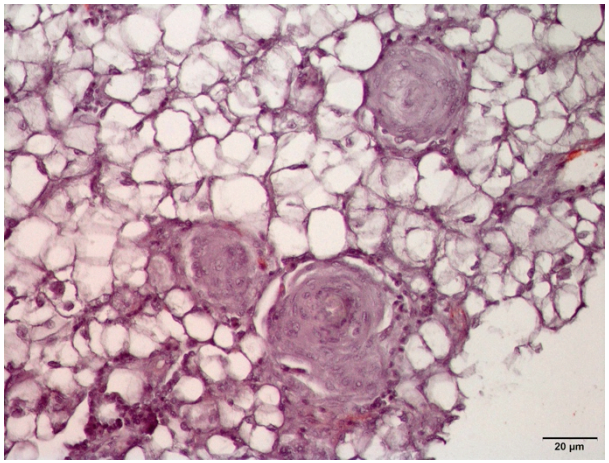
Granuloma severity in **heart**

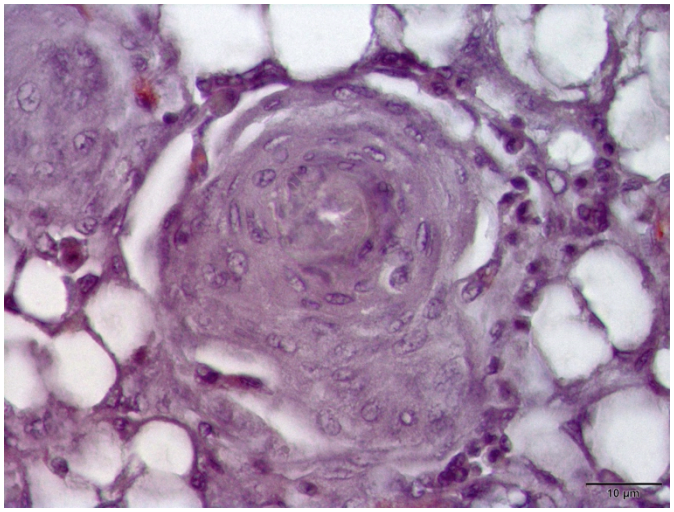


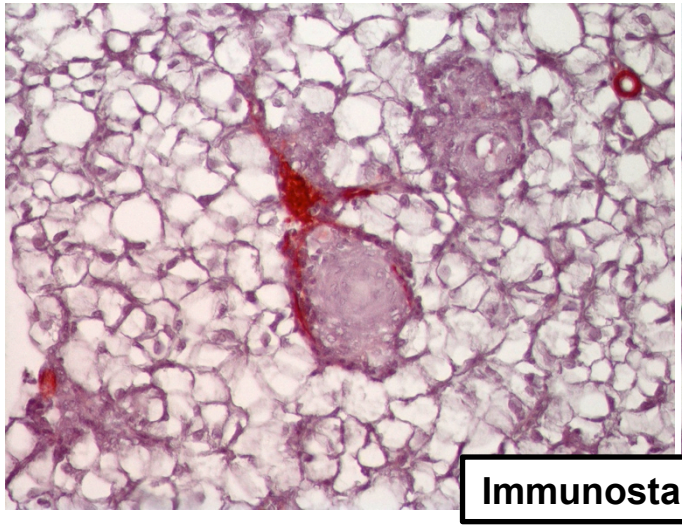
% Fish with different severity of granuloma in heart

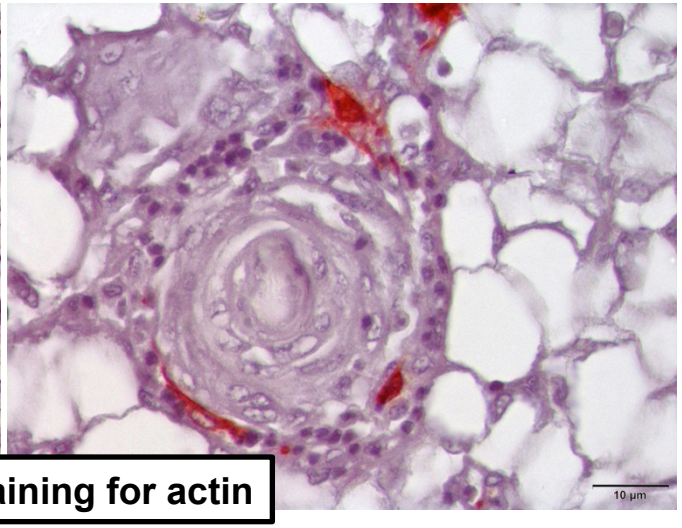


Granuloma formation





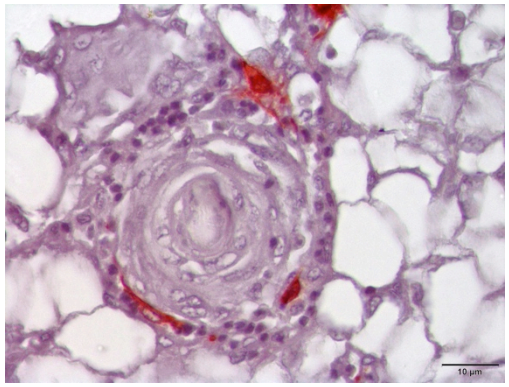




Immunostaining for actin

Granulomas were initiated always in the blood vessels, with inflammation of the endothelial cells, alteration of vascular permeability and causing vascular dysfunction, but severity was reduced by vit E & C supplementation No calcification was observed

Granuloma formation



Oxidative stress promotes vascular dysfunction, inducing altered vascular permeability and inflammation and the aberrant expression of inflammatory adhesion

Vitamin E and vitamin C counteract lipid peroxidative damage restoring vascular function and protecting endotelial tissue in blood vessels.

Vitamin K supplementation improves arterial stiffness in mammals and could contribute to reduce the severity of the lessions

- Dietary addition of vitamins E and C improved meagre growth performance.
- Increase in dietary vit E and C reduced granulomas incidence and severity, particularly with supplementation of vit K
- The granuloma formation was initiated in blood vessels were oxidative stress would affect endotelial tissue causing vascular dysfunction, altered vascular permeability and inflammation.

Aquaculture Research

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Thanks for your attention

The importance of dietary HUFA for meagre larvae (*Argyrosomus regius*; Asso, 1801) and its relation with antioxidant vitamins E and C

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Dietary combination of vitamin E, C and K affects growth, antioxidant activity, and the incidence of systemic granulomatosis in meagre (*Argyrosomus regius*)

Ruiz, M.A. [a] ✉, Betancor, M.B. [b], Robaina, L. [a], Montero, D. [a], Hernández-Cruz, C.M. [a], Izquierdo, M.S. [a], Rosenlund, G. [c], Fontanillas, R. [c], Caballero, M.J. [a]

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Volume 488, 10 March 2018, Pages 105-113

Dietary requirement for n-3 long-chain polyunsaturated fatty acids for fast growth of meagre (*Argyrosomus regius,* Asso 1801) fingerlings

Carvalho, M. [a, b, c] ✉, Peres, H. [b, c], Saleh, R. [a, d], Fontanillas, R. [e], Rosenlund, G. [e], Oliva-Teles, A. [b, c], Izquierdo, M. [a]