



**ADVANCING  
PERFORMANCE  
TOGETHER**

**Essential  
Trace Minerals**  
for Exceptional  
Performance





# Zinpro Performance Minerals® deliver proven benefits for Shrimp Performance, Health and Meat Quality

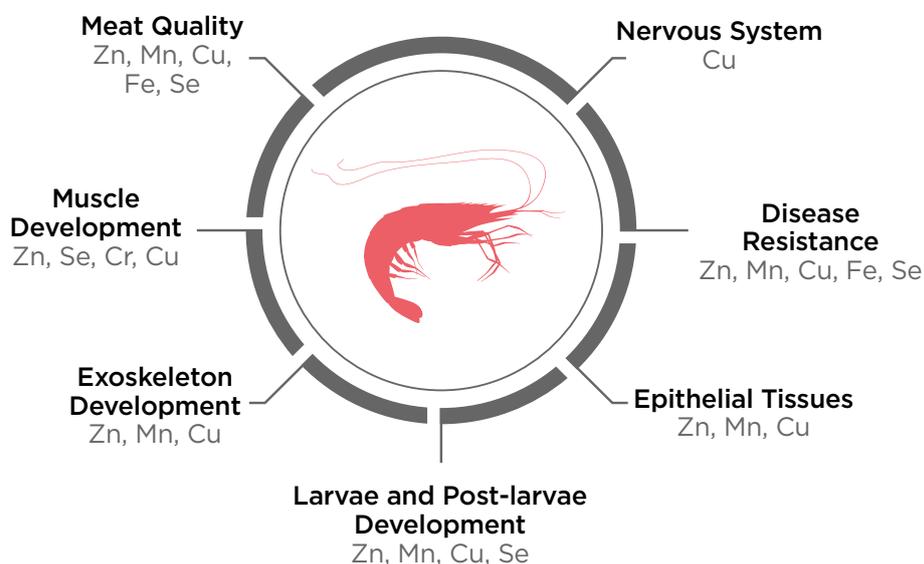
Trace minerals play numerous essential roles within cells and metabolic processes, which makes them vital for optimal nutrition and health of animals – including shrimp.

Research shows shrimp diets with Zinpro Performance Minerals® (ZPM) optimizes growth and improves animal wellness through modulation of the immune system. In addition, meat quality is improved, as measured by color, drip loss, lipid oxidation and nutritional value.

The source and availability of trace minerals is key to satisfy the needs of shrimp in an efficient and sustainable way throughout their life cycle.

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## Trace Mineral Benefits in Shrimp



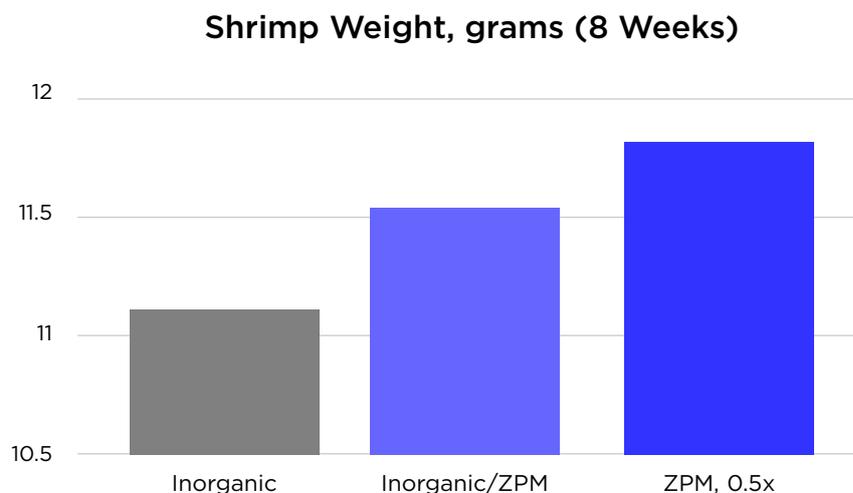
## Study 1

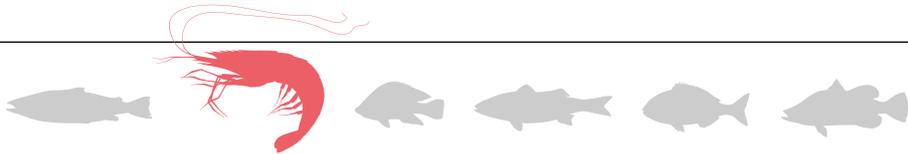
# Comparison of Whiteleg Shrimp Response to Inorganic Minerals and Zinpro Performance Minerals® (0.5x)

## Key Findings

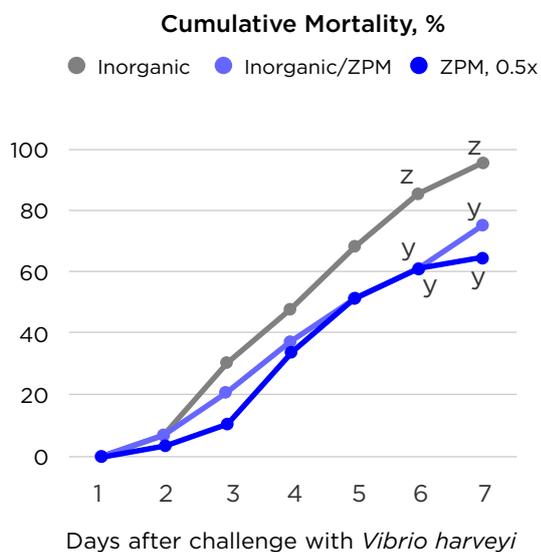
- Zinpro Performance Minerals (ZPM) supplemented at half the level of inorganic mineral sources resulted in numerically higher final body weight (Fig. 1).
- Return on investment (ROI), as measured by additional income over feed cost, was 16% more for shrimp fed ZPM at 0.5x rate as compared to shrimp fed inorganic minerals. ROI for the combination of inorganic and ZPM was 11% more than inorganic alone.
- Cumulative mortality of shrimp challenged with *Vibrio harveyi* was significantly ( $P < 0.05$ ) reduced when inorganic mineral sources were partially or completely replaced with ZPM (Fig. 2).
- Furthermore, drip loss of peeled white shrimp was significantly ( $P < 0.05$ ) lower for shrimp fed diets supplemented with ZPM (Fig. 3).

### Growth Performance Fig. 1

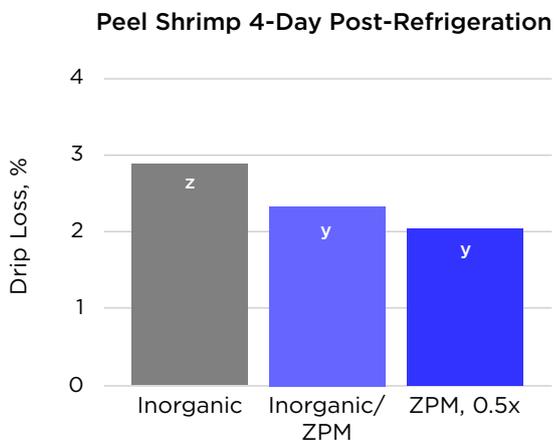




## Health Fig. 2



## Meat Quality Fig. 3



## Study Criteria



This study compared the efficacy of Zinpro Performance Minerals (metal-amino acid complexes) with inorganic minerals (sulfates) in the diet for whiteleg shrimp. Growth performance, resistance to bacterial challenge *Vibrio harveyi*, and meat quality were evaluated.



	Inorganic (sulfate)	Inorg + ZPM	ZPM (0.5x)
Zinc (ppm)	120	70	60
Manganese (ppm)	60	40	30
Copper (ppm)	32	22	16
Iron (ppm)	100	50	50
Selenium (ppm)	0.3	0	0.15



Initial body weight: 4.4g  
 Stocking density: 70 shrimp/m<sup>2</sup>  
 Feeding: 4x per day  
 Replications: 6  
 Feeding period: 8 weeks  
 Salinity: 12ppt



35.5% CP/7.5% Fat  
 25% fish meal  
 3% shrimp meal  
 2% squid meal  
 20% soybean meal  
 5% poultry by-product meal



Location:  
 Kasetsart University, Thailand

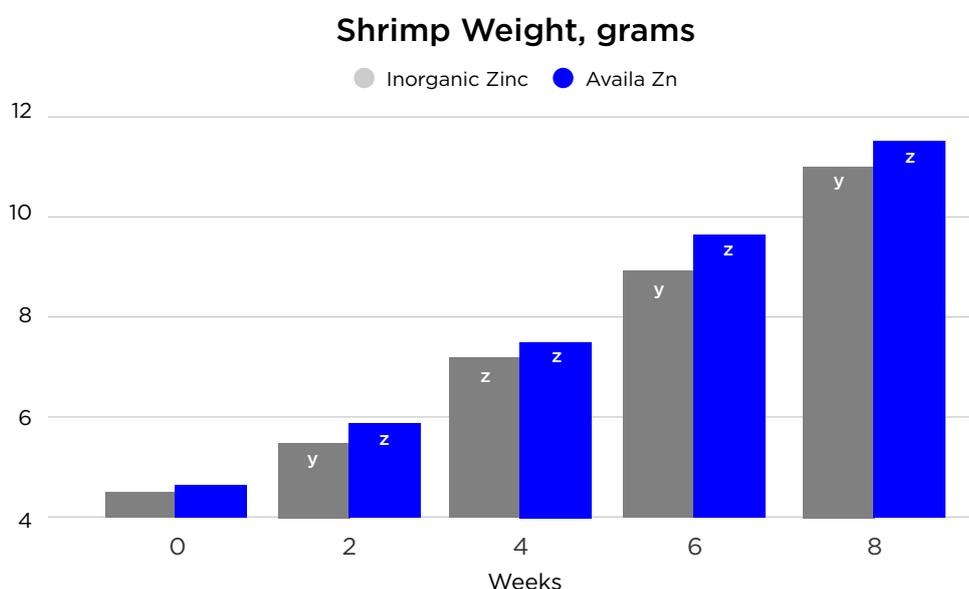
## Study 2

# Availa<sup>®</sup>Zn and Availa<sup>®</sup>Se Supplementation Improves Growth, Health and Meat Quality

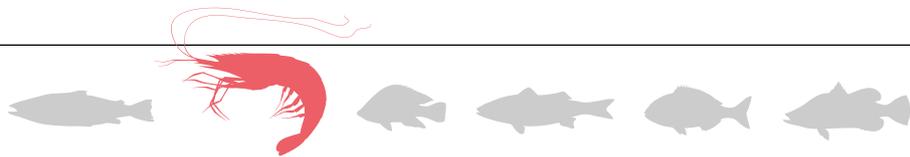
## Key Findings

- Partial replacement of inorganic zinc with Availa Zn significantly ( $P < 0.05$ ) improved shrimp weight (Fig. 1).
- Partial replacement of inorganic zinc and selenium with Availa Zn and Availa Se significantly ( $P < 0.05$ ) increased hemocyte count and phenoloxidase activity, key biomarkers of shrimp immune response (Fig. 2).
- Modulation of the immune response by ZPM resulted in reduced cumulative mortality of shrimp challenged by *Vibrio harveyi*.
- Availa Se significantly ( $P < 0.05$ ) improved redness of 72-hour chilled shrimp meat, before and after boiling (data not shown). Availa Se also significantly ( $P < 0.05$ ) improved redness of shrimp meat frozen for 14 days (Fig. 3).
- Whole shrimp drip-loss and meat rancidity were both significantly ( $P < 0.05$ ) reduced by partially replacing inorganic Se with Availa Se (Fig. 3). Moreover, the effect of partially replacing inorganic Zn with Availa Zn on drip-loss tended to be more evident when an inorganic source of Se was used.
- Zn and Se accumulation significantly ( $P < 0.05$ ) increased in the exoskeleton and hepatopancreas for shrimp fed Availa Zn and Availa Se (data not shown).

## Growth Performance Fig. 1

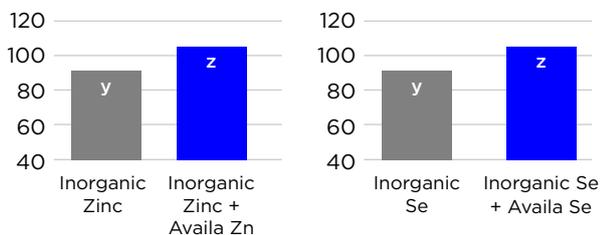


Source: Mihai Sun, Terry Ward, Orapint Jintasataporn, Claudia Silva 2018. Efficacy of Availa Zn and Availa Se for White Shrimp (*Litopenaeus vannamei*). International Symposium on the Feeding and Nutrition of Fish, June 3-7, 2018, Las Palmas, Gran Canaria, Spain



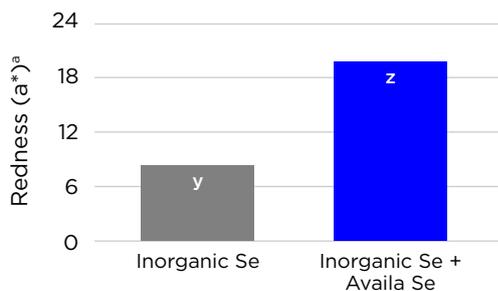
## Health Fig. 2

**Phenoloxidase Activity**  
Units/min/mg protein



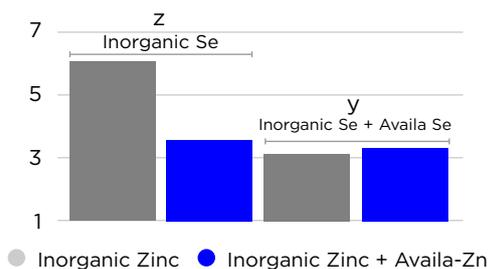
## Meat Quality Fig. 3

**Shrimp Meat Color**  
Boiled after 72-hours chilled



<sup>a</sup> Higher redness value (a\*) indicates redder color (+60 for red to -60 for green)

**Drip Loss, %**  
Whole shrimp, after 72-hours chilled



● Inorganic Zinc ● Inorganic Zinc + Availa-Zn

## Study Criteria



This study evaluated the effects of partially replacing inorganic Zn and Se with Zn from Availa Zn and Se from Availa Se on whiteleg shrimp growth performance, health and meat quality.



	Inorganic Zn Inorganic Se	Availa Zn <sup>a</sup> Inorganic Se	Inorganic Zn Availa Se <sup>b</sup>	Availa Zn Availa Se
Zinc sulfate (ppm)	120	70	120	70
Availa-Zn (ppm)		50		50
Sodium selenite (ppm)	0.30	0.30	0.15	0.15
Availa-Se (ppm)			0.15	0.15

<sup>a</sup> Availa Zn zinc amino acid complex

<sup>b</sup> Availa Se zinc-L-selenomethionine



Initial body weight: 4g  
Stocking density: 60 shrimp/m<sup>2</sup>  
Feeding: 4x per day  
Replications: 6  
Feeding period: 8 weeks  
Salinity: 30ppt



36.5% CP/8% fat  
25% fish meal  
3% shrimp meal  
2% squid meal  
20% soybean meal  
5% poultry by-product



Location:  
Kasetsart University, Thailand

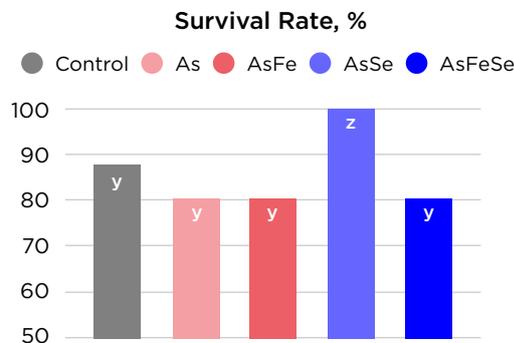
## Study 3

# Supplementation with Availa®Fe and Availa®Se are Key in Coloration of Whiteleg Shrimp

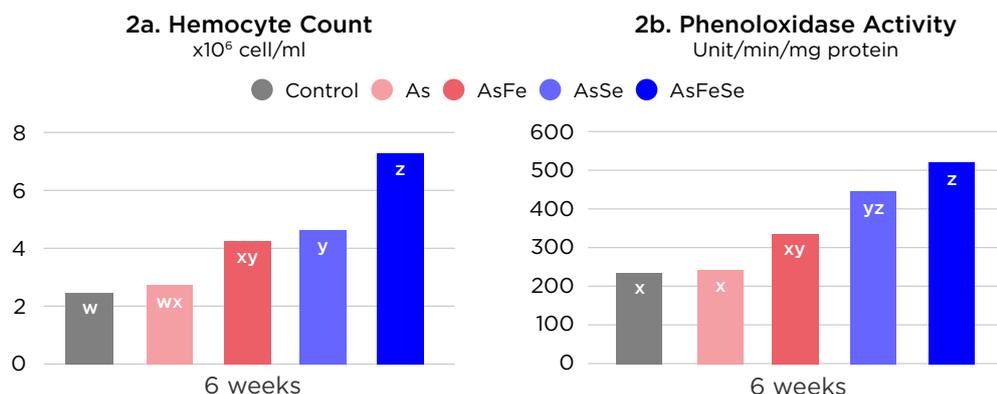
## Key Findings

- Diets supplemented with Availa Se showed improvements in survival rate (Fig. 1) and FCR (data not shown).
- The diet containing astaxanthin (As), Availa Se and Availa Fe significantly ( $P < 0.05$ ) increased the hemocyte count and phenoloxidase activity (Fig. 2).
- Diet supplemented with 75ppm astaxanthin, 200ppm Availa Fe and 0.3ppm Availa Se (AsFeSe) significantly ( $P < 0.05$ ) enhanced shrimp meat redness as indicated by the  $a^*$  value and total carotenoid content of cooked shrimp shell and flesh (Fig. 3). SalmoFan™ was able to score an increase in shrimp color from 23 to 29 in only four weeks with AsFeSe (data not shown).

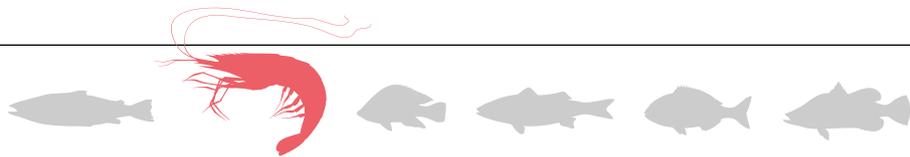
### Growth Performance Fig. 1



### Health Fig. 2

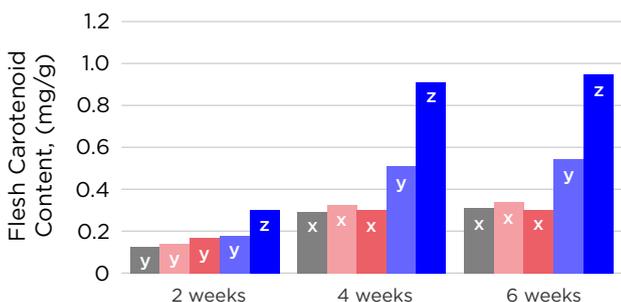
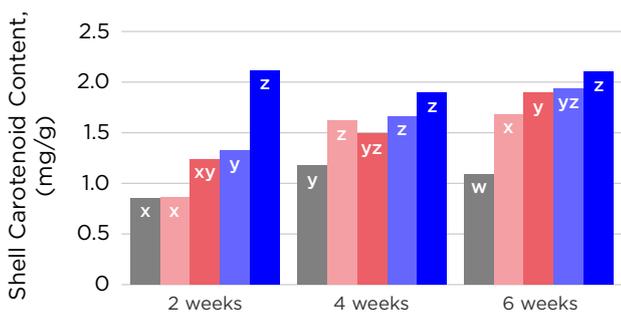
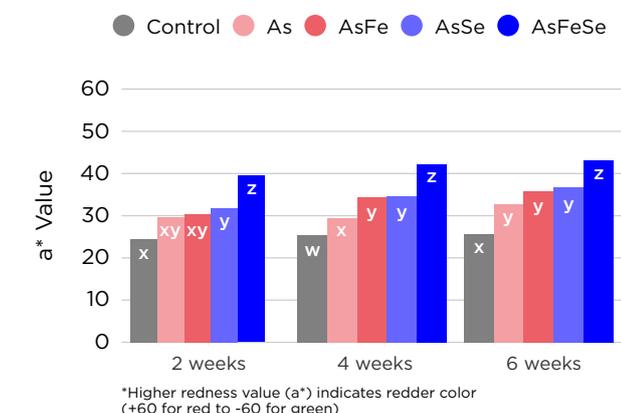


Source: Jintasataporn, O., Ward, T., Chalemlap, S., Chumkam, S. Iron amino acid complex (Availa Fe) and zinc-L-selenomethionine (Availa Se) in diets enhance cooked Pacific white shrimp (*Litopenaeus vannamei*) color. International Symposium on the Feeding and Nutrition of Fish, June 3-7, 2018, Las Palmas, Gran Canaria, Spain.



## Meat Quality Fig. 3

The a\* Value of Cooked Shrimp Fed with 5 Different Experimental Diets for 6 Weeks



## Study Criteria



This study was conducted to investigate shrimp coloration and immune response when astaxanthin was added to the diet alone or in combination with either iron or selenium, or with both iron and selenium.



Treatments	Astaxanthin (ppm)	Availa Fe (ppm)	Availa Se (ppm)
Control	-	-	-
As	75	-	-
AsFe	75	200	-
AsSe	75	-	0.3
AsFeSe	75	200	0.3



Initial body weight: c.a. 6.5g  
 Stocking density: 10 shrimp/100L aquarium  
 Feeding: 3x per day  
 Replications: 4  
 Feeding period: 6 weeks



12.5% fish meal  
 3% squid meal  
 25% soybean meal  
 7.5% soy protein concentrate  
 3% yeast  
 10% wheat gluten  
 22% wheat flour



Location:  
 Kasetsart University, Thailand

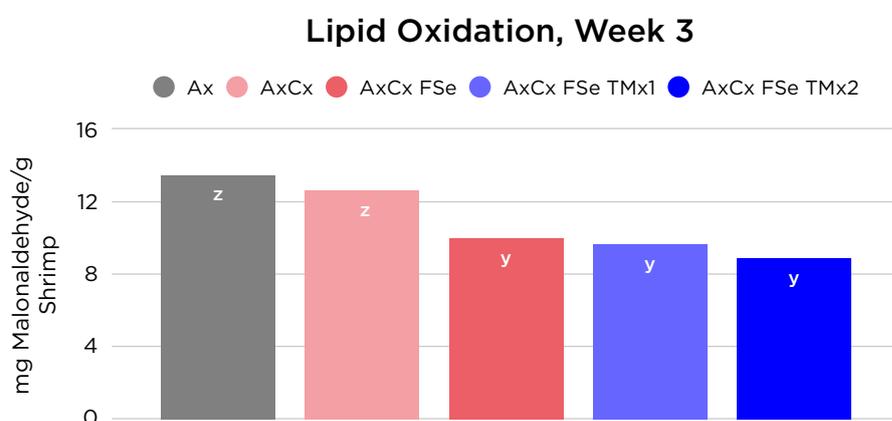
## Study 4

# Zinpro Performance Minerals® Spare Carotenoids For Pigmentation Purposes

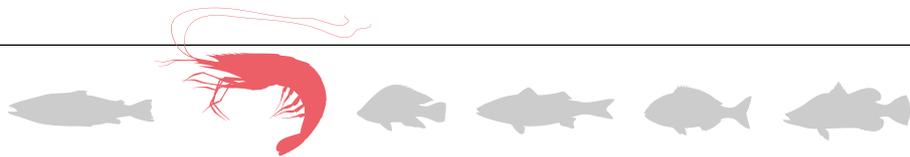
## Key Findings

- Supplementation with ZPM can effectively and economically support the reduction of astaxanthin while maintaining cooked shrimp color, performance and health parameters (data not shown).
- The reduction of astaxanthin from 75 to 25ppm in combination with 25ppm canthaxanthin had no effect on lipid oxidation (Fig. 1) but it reduced meat and shell redness as indicated by a\* value (Fig. 2) and SalmoFan™ scores (Fig. 3).
- SalmoFan scores of shrimp shell dropped from 27 to 24.4 in only 3 weeks when fed 25ppm astaxanthin in combination with 25ppm canthaxanthin and no ZPM.
- Supplementation with 100ppm Fe as Availa®Fe, 0.3ppm Se as Availa®Se, 100ppm Zn as Availa®Zn, 40ppm Mn as Availa®Mn and 20ppm Cu as Availa®Cu to AxCx diet (25ppm astaxanthin 25ppm canthaxanthin) increased SalmoFan score of shrimp shell back to that of control diet (75ppm astaxanthin).
- ZPM supplementation reduced lipid oxidation, measured as milligram malonaldehyde per gram shrimp (Fig. 1) highlighting antioxidant functions of TM as co-factors of key antioxidant enzymes.
- Results indicate that supplementation with ZPM (AxCx FSe TMx2 treatment) can boost shrimp antioxidant capacity in only 3 weeks, allowing astaxanthin to be diverted for pigmentation purposes instead of antioxidant functions (sparing effect) saving \$66 US per ton of feed.

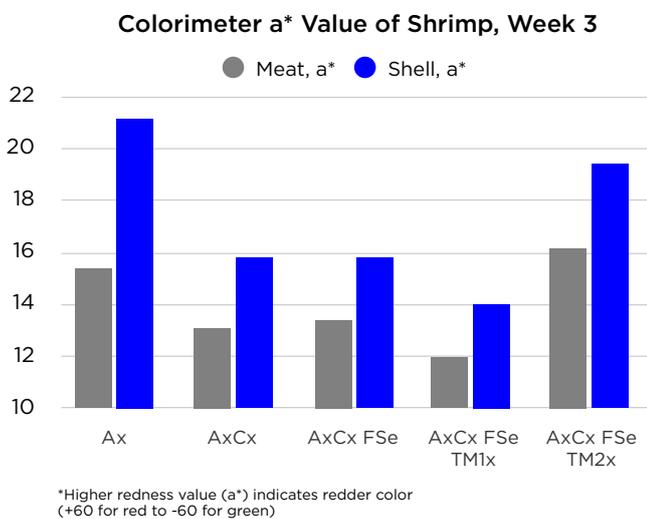
## Meat Quality Fig. 1



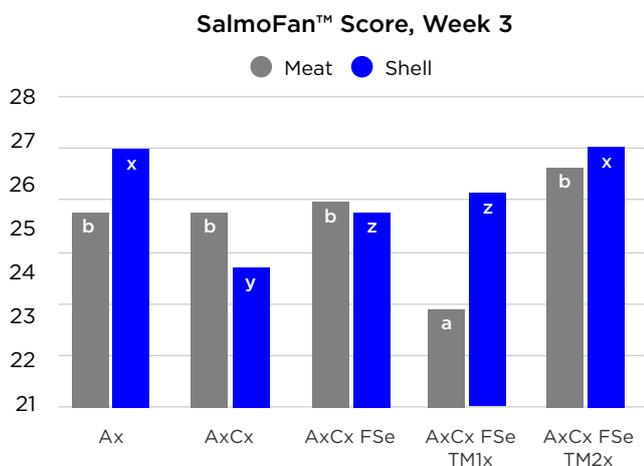
Source: Boggino *et al.*, 2020. Trace Mineral Amino Acid Complexes (Availa Zn, Mn, Cu and Fe) and Zn-L-Selenomethionine (Availa Se) in white leg shrimp (*Litopenaeus vannamei*) Diets Enhance Cooked Shrimp Color. Aquaculture America, February 9-12th, 2020, Hawaii.



## Meat Quality Fig. 2



## Meat Quality Fig. 3



## Study Criteria



Trace minerals participate as cofactors of important enzymes related to the antioxidant defense mechanism. This study evaluated their effect on sparing carotenoids for pigmentation purposes.



Treatment	Carotenoids <sup>a</sup> , ppm		ZPM <sup>b</sup> , ppm				
	ASTX	CANX	Availa Fe	Availa Se	Availa Zn	Availa Mn	Availa Cu
Ax	75	-	-	-	-	-	-
AxCx	25	25	-	-	-	-	-
AxCx FSe	25	25	100	0.3	-	-	-
AxCx FSe TMx1	25	25	100	0.3	50	20	10
AxCx FSe TMx2	25	25	100	0.3	100	40	20

<sup>a</sup> Wisdom pink 10%, Wisdom red 10%; ASTX = astaxanthin, CANX = canthaxanthin  
<sup>b</sup> ZPM were supplemented on top of basal diet that included inorganic premix (mg/kg diet): 0.2 Co, 25 Cu, 11, 30 Fe, 30 Mn, 0.35 Se, 100 Zn.



Initial body weight: 7-8g  
 Stocking density: 20 shrimp/300L tank  
 Feeding: 3x per day  
 Replications: 5  
 Feeding period: 3 weeks  
 Salinity: 10-15ppt



38% CP/6% Fat  
 12.5% fish meal  
 3% squid meal  
 25% soybean meal  
 7.5% fermented soy meal  
 3% yeast  
 10% wheat gluten  
 22% wheat flour



Location:  
 Kasetsart University, Thailand

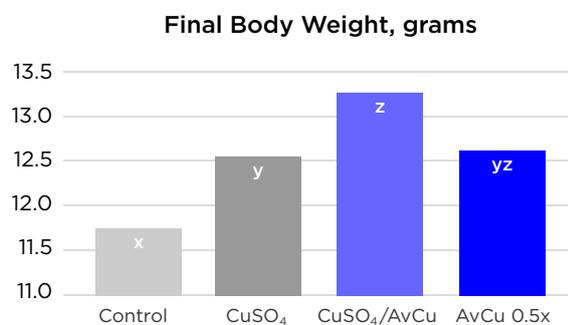
## Study 5

# A. Effect of Copper Source on Growth and Intestinal Microbial Communities of Whiteleg Shrimp

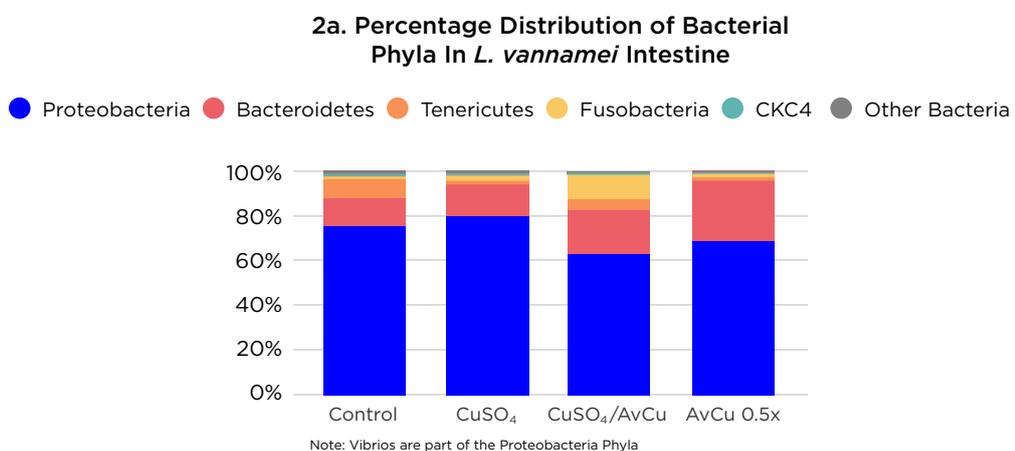
## Key Findings

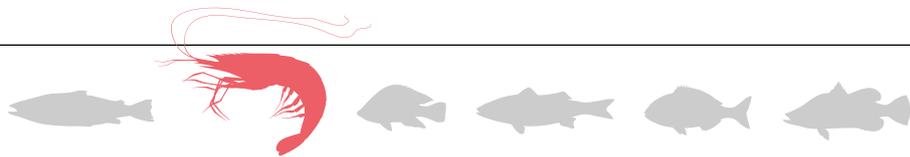
- Cu supplementation positively affected growth of shrimp.
- Availa®Cu at 0.5x rate (15ppm Cu) of CuSO<sub>4</sub> (30ppm Cu) maintained shrimp FBW (Fig. 1), showing Availa Cu is more effective than inorganic Cu.
- Marked trends in microbial phyla suggest microbial communities were being influenced by copper source (Fig. 2a).
- Combination of Availa Cu + CuSO<sub>4</sub> Cu (total 30ppm Cu) resulted in numerically better growth than Availa Cu at 0.5x rate, indicating higher Cu supplementation may be required for maximized shrimp performance.
- The reduction on *Proteobacteria* phylum which includes the *Vibriocaceae* family is related to overall shrimp health when a fed combination of CuSO<sub>4</sub> and Availa Cu or Availa Cu at 0.5x rate.

## Growth Performance Fig. 1



## Health Fig. 2



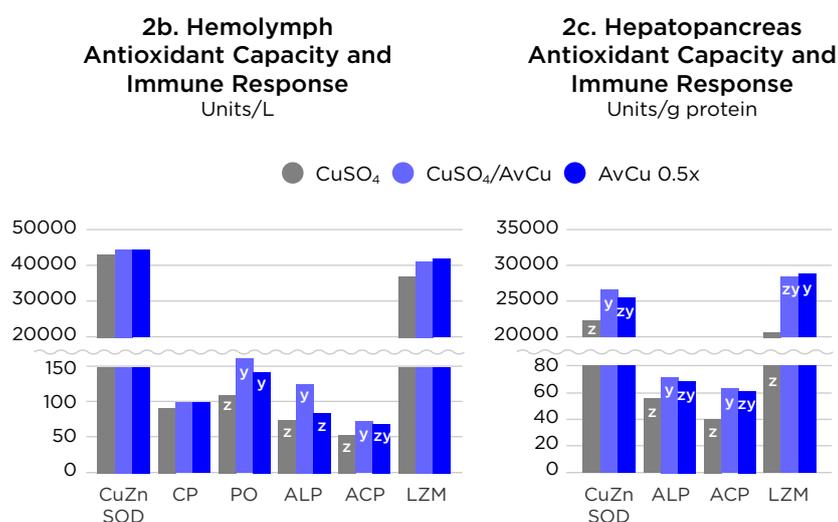


# B. Effect of Copper Source on Shrimp Antioxidant Capacity and Immune Response

## Key Findings

- Partial or complete replacement of CuSO<sub>4</sub> with Availa Cu at 0.5x rate significantly improved phenoloxidase activity in hemolymph (Fig. 2b).
- Partial or complete replacement of CuSO<sub>4</sub> with Availa Cu at 0.5x rate increased hepatopancreatic Cu/Zn SOD, ALP and ACP indicating better antioxidant capacity and immune response in shrimp fed Availa Cu.
- Activity of hepatopancreatic LZM was significantly increased in shrimp fed Availa Cu at 0.5x rate (Fig. 2c).
- Activities of hepatopancreatic Cu/Zn SOD, ALP and ACP were highest when the treatment was combined, but not statistically different from Availa Cu at 0.5x.
- The inclusion of optimal levels of Availa Cu in shrimp diets improved shrimp health biomarkers, demonstrating that robust shrimp can be grown under commercial conditions.

Health Fig. 2



## Study Criteria



This study evaluated effects of dietary copper source on shrimp growth, intestinal microbial communities, antioxidant and immune response.



Trace Mineral	Treatment, ppm added to Control			
	Control	CuSO <sub>4</sub>	CuSO <sub>4</sub> / AvCu	AvCu 0.5x
Copper	0	30	15/15	15

\* Diet contains 10 ppm of Copper coming from raw material.



Initial body weight: 1.86 g IBW  
Stocking density: 30 shrimp/tank  
Feeding: 3x per day  
Replications: 3  
Feeding period: 8 weeks  
Salinity: 25-28ppt



43% CP/8% Fat  
30% fish meal  
3% krill meal  
22% soybean meal  
6% poultry by-product  
6% peanut meal



Location:  
Ningbo University, China

Source: Yuan *et al.*, 2019b. Effects of dietary dosage forms of copper supplementation on growth antioxidant capacity, innate immunity enzyme and gene expressions for juvenile *Litopenaeus vannamei*. Fish and Shellfish Immunology 84:1059-1067

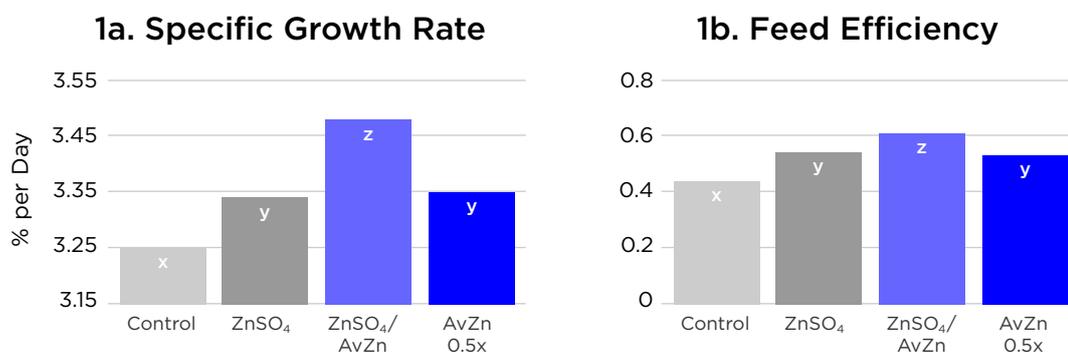
## Study 6

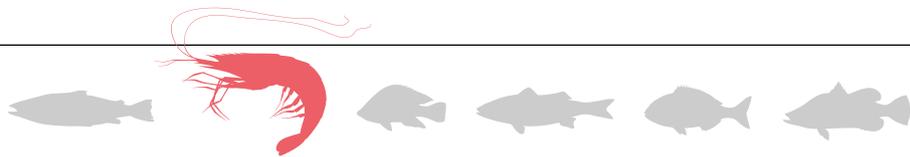
# Effect of Zinc Source and Level on Shrimp Growth Performance, Meat Quality, Antioxidant and Immune Capacity

## Key Findings

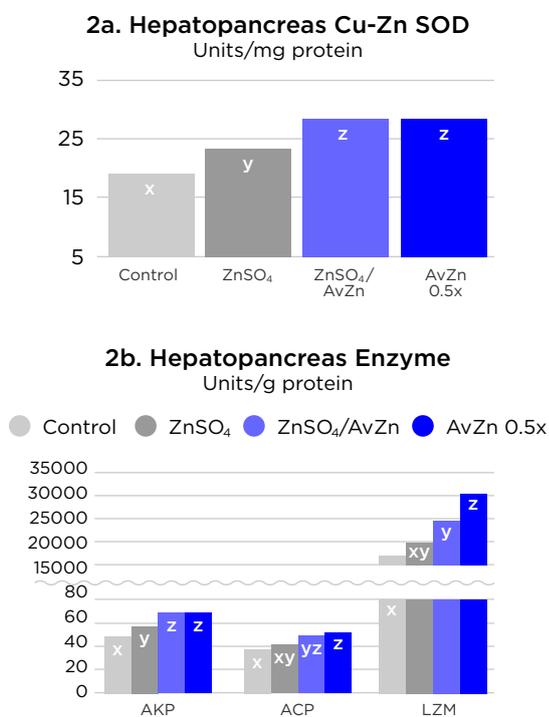
- Availa<sup>®</sup>Zn at 0.5x rate (60ppm Zn) of ZnSO<sub>4</sub> maintained Specific Growth Rate (SGR) (Fig. 1a) and Feed Efficiency (FE) (Fig. 1b), showing Availa Zn is more effective than inorganic Zn.
- The combination of 60ppm Availa Zn + 60ppm ZnSO<sub>4</sub> improved shrimp survival rate (data not shown), SGR and FE by 4.3, 3.1 and 20% respectively (Fig. 1a & 1b).
- Hepatopancreas antioxidant (Fig. 2a) and immune-related enzymes (Fig. 2b) were higher in shrimp fed a combination of ZnSO<sub>4</sub> and Availa Zn or Availa Zn at 0.5x rate.
- Availa Zn in combination with ZnSO<sub>4</sub> or at 0.5x rate, reduced drip loss in muscle (Fig. 3a) and drip loss and thaw loss in whole shrimp (Fig. 3b).
- Availa Zn in combination with ZnSO<sub>4</sub> or at 0.5x rate translated to an economic advantage over the control (ROI) of 45.6% and 24.5%, respectively.
- Best performance was with the combination of 60ppm Zn as ZnSO<sub>4</sub> + 60ppm Zn as Availa Zn, which indicates higher Zn supplementation may be required for maximized shrimp performance.
- ROI for Availa Zn at 0.5x rate is underestimated due to the difficulty in attributing economic value to benefits seen on antioxidant defense, immune response and product quality. Higher ROI is expected in the field and under more challenging conditions.

## Growth Performance Fig. 1

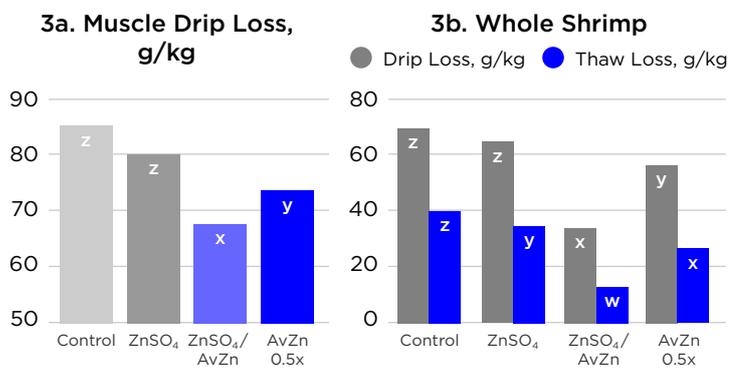




## Health Fig. 2



## Meat Quality Fig. 3



## Study Criteria



This study aimed to provide novel insight into how the supplementation and level of a Zn source effected whiteleg shrimp: growth response, meat quality, oxidation resistance and innate immunity.



Trace Mineral	Treatment, ppm added to Control			
	Control	ZnSO <sub>4</sub>	ZnSO <sub>4</sub> / AvZn	AvZn 0.5x
Copper	0	120	60/60	60

Note: Basal diet contains 51 ppm of Zinc coming from raw material.



Initial body weight: 1.84g  
Stocking density: 30 shrimp/tank  
Feeding: 3x per day  
Replications: 4  
Feeding period: 8 weeks  
Salinity: 25-28ppt



43% CP/7.6% fat  
30% fish meal  
3% krill meal  
22% soybean meal  
6% poultry by-product meal  
6% peanut meal



Location:  
Ningbo University, China

# Essential Trace Minerals for Shrimp

BENEFIT	TRACE MINERALS	DESCRIPTION
Disease Resistance	Zinc, Manganese, Copper, Selenium, Iron	<ul style="list-style-type: none"> <li>• Humoral immunity</li> <li>• Cell-mediated immunity</li> <li>• Antioxidant activity to remove free radicals and protect cell membranes</li> </ul>
Exoskeleton Health	Zinc, Manganese, Copper	<ul style="list-style-type: none"> <li>• Exoskeleton formation, development and reconstruction during molting</li> <li>• Cell division and protein synthesis for normal tissue mineralization</li> </ul>
Gut Integrity	Zinc, Manganese, Copper	<ul style="list-style-type: none"> <li>• Improves wound healing</li> <li>• Epithelial tissue integrity through maintaining of cell division, protein synthesis and antioxidant activity to remove superoxide radicals</li> </ul>
Muscle Development	Zinc, Selenium, Chromium, Copper	<ul style="list-style-type: none"> <li>• Enzyme systems required for growth</li> <li>• Energy and protein metabolism</li> <li>• Cell membrane protection from peroxides</li> <li>• Influences carbohydrate, lipid and protein metabolism</li> <li>• Oxygen carrying function</li> </ul>
Early Stage Development	Zinc, Manganese, Copper, Selenium	<ul style="list-style-type: none"> <li>• Energy and protein metabolism</li> <li>• Cell proliferation</li> <li>• Normal tissue mineralization</li> <li>• Cell membrane protection</li> <li>• Hematopoiesis, the formation of hemocyanin, a large copper-containing protein that serve as the oxygen-carrying in the hemolymph</li> </ul>
Meat Quality	Zinc, Selenium, Chromium, Iron	<ul style="list-style-type: none"> <li>• Cell membrane protection</li> <li>• Antioxidant activity</li> <li>• Influences carbohydrate, lipid and protein metabolism</li> <li>• Enhanced meat color</li> </ul>



# Feeding Recommendations for Shrimp

Mineral	Zinpro Performance Minerals® Products	Zinpro Recommendations Minimum Requirement ZPM, mg/kg diet
Zn	Availa® Zn ProPath® Zn	60
Cu	Availa® Cu ProPath® Cu	40
Mn	Availa® Mn ProPath® Mn	40
Fe	Availa® Fe ProPath® Fe	50
I <sup>a</sup>		4
Se <sup>b</sup>	Availa® Se	0.3
Cr <sup>c</sup>	MICROPLEX® Availa® Cr	0.4

<sup>a</sup> Not a current ZPM source

<sup>b</sup> Note upper limit allowed in EU is of 0.2 ppm, provided as organic source

<sup>c</sup> Use where commercially available



**Trace minerals are vital for optimal shrimp nutrition.**



Improving the wellness  
and performance of  
animals for a  
**healthier, more  
sustainable world.**



For more information:  
contact your Zinpro sales  
representative or visit  
[zinpro.com/aquaculture](https://zinpro.com/aquaculture)