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 that supplementing shrimp diets with Zinpro Performance Minerals is essential for optimizing growth and improving animal wellness through modulation of the immune system. In addition, meat quality is improved, as measured by color and drip loss.

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.

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

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.

<table>
<thead>
<tr>
<th>Inorganic (sulfate)</th>
<th>Inorg + ZPM</th>
<th>ZPM (0.5x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc (ppm)</td>
<td>120</td>
<td>70</td>
</tr>
<tr>
<td>Manganese (ppm)</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Copper (ppm)</td>
<td>32</td>
<td>22</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Selenium (ppm)</td>
<td>0.3</td>
<td>0</td>
</tr>
</tbody>
</table>

Initial body weight: 4.4g
Stocking density: 70 shrimp/m²
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
Availa® Zn and Availa® 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**

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Inorganic Zinc</th>
<th>Availa Zn</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>4.4</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>5.5</td>
<td>5.8*</td>
</tr>
<tr>
<td>4</td>
<td>7.3</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>8.9</td>
<td>9.6*</td>
</tr>
<tr>
<td>8</td>
<td>11.0*</td>
<td>11.6*</td>
</tr>
</tbody>
</table>

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.

### Study Criteria

- **Initial body weight:** 4g
- **Stocking density:** 60 shrimp/m²
- **Feeding:** 4x per day
- **Replications:** 6
- **Feeding period:** 8 weeks
- **Salinity:** 30ppt

### Nutritional Composition

- **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
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

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.

**Meat Quality**  
Fig. 3

The *a* value of cooked shrimp fed with 5 different experimental diets for 6 weeks:

- **Control**
- **As**
- **AsFe**
- **AsSe**
- **AsFeSe**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Astaxanthin (ppm)</th>
<th>Availa Fe (ppm)</th>
<th>Availa Se (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>As</td>
<td>75</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AsFe</td>
<td>75</td>
<td>200</td>
<td>-</td>
</tr>
<tr>
<td>AsSe</td>
<td>75</td>
<td>-</td>
<td>0.3</td>
</tr>
<tr>
<td>AsFeSe</td>
<td>75</td>
<td>200</td>
<td>0.3</td>
</tr>
</tbody>
</table>

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
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

Lipid Oxidation, Week 3

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.

**Study Criteria**

- 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

**Meat Quality** Fig. 2

**Colorimeter a* Value of Shrimp, Week 3**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ASTX</th>
<th>CANX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ax</td>
<td>75</td>
<td>-</td>
</tr>
<tr>
<td>AvCx</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>AvCx FSe</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>AvCx FSe TM1x</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>AvCx FSe TM2x</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

- Wisdom pink 10%, Wisdom red 10%; ASTX = astaxanthin, CANX = canthaxanthin
- ZPM were supplemented on top of basal diet that included inorganic premix (mg/kg diet) - 0.2 Co, 25 Cu, 1 I, 30 Fe, 30 Mn, 0.35 Se, 100 Zn.

**Meat Quality** Fig. 3

**SalmoFan™ Score, Week 3**

- Ax AxCx AxCx FSe AxCx FSe AxCx FSe TM1x TM2x

- Meat, a* Shell, a*

**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
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$_4$ (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$_4$ 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 Vibrioceae family is related to overall shrimp health when a fed combination of CuSO$_4$ and Availa Cu or Availa Cu at 0.5x rate.

Growth Performance Fig. 1

![Final Body Weight, gram](chart)

Health Fig. 2

2a. Percentage Distribution of Bacterial Phyla in L. vannamei Intestine

![Percentage Distribution Chart](chart)

Note: Vibrios are part of the Proteobacteria Phyla

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

Key Findings

- Partial or complete replacement of CuSO₄ with Availa Cu at 0.5x rate significantly improved phenoloxidase activity in hemolymph (Fig. 2b).
- Partial or complete replacement of CuSO₄ 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

2b. Hemolymph Antioxidant Capacity and Immune Response

<table>
<thead>
<tr>
<th>Units/L</th>
<th>CuSO₄</th>
<th>CuSO₄/AvCu</th>
<th>AvCu 0.5x</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuZn SOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
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<td>15</td>
<td>15</td>
</tr>
<tr>
<td>PO</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>ALP</td>
<td>15</td>
<td>15</td>
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</tr>
<tr>
<td>ACP</td>
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<tr>
<td>LZM</td>
<td>15</td>
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2c. Hepatopancreas Antioxidant Capacity and Immune Response

<table>
<thead>
<tr>
<th>Units/g protein</th>
<th>CuSO₄</th>
<th>CuSO₄/AvCu</th>
<th>AvCu 0.5x</th>
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</thead>
<tbody>
<tr>
<td>CuZn SOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALP</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>ACP</td>
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<td>15</td>
</tr>
<tr>
<td>LZM</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

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®Zn at 0.5x rate (60ppm Zn) of ZnSO₄ 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 ZnSO₄ 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 ZnSO₄ and Availa Zn or Availa Zn at 0.5x rate.

- Availa Zn in combination with ZnSO₄ 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 ZnSO₄ 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 ZnSO₄ + 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

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, innate immunity.

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

<table>
<thead>
<tr>
<th>BENEFIT</th>
<th>TRACE MINERALS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
</table>
| Disease Resistance            | Zinc, Manganese, Copper, Selenium, Iron | • Humoral immunity  
• Cell-mediated immunity  
• Antioxidant activity to remove free radicals and protect cell membranes |
| Exoskeleton Health            | Zinc, Manganese, Copper          | • Exoskeleton formation, development and reconstruction during molting  
• Cell division and protein synthesis for normal tissue mineralization      |
| Gut Integrity                 | Zinc, Manganese, Copper          | • Improves wound healing  
• Epithelial tissue integrity through maintaining of cell division, protein synthesis and antioxidant activity to remove superoxide radicals |
| Muscle Development            | Zinc, Selenium, Chromium, Copper | • Enzyme systems required for growth  
• Energy and protein metabolism  
• Cell membrane protection from peroxides  
• Influences carbohydrate, lipid and protein metabolism  
• Oxygen carrying function |
| Early Stage Development       | Zinc, Manganese, Copper, Selenium | • Energy and protein metabolism  
• Cell proliferation  
• Normal tissue mineralization  
• Cell membrane protection  
• Hematopoiesis, the formation of hemocyanin, a large copper-containing protein that serve as the oxygen-carrying in the hemolymph |
| Meat Quality                  | Zinc, Selenium, Chromium, Iron  | • Cell membrane protection  
• Antioxidant activity  
• Influences carbohydrate, lipid and protein metabolism  
• Enhanced meat color |

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## Shrimp Feeding Recommendations

<table>
<thead>
<tr>
<th>Mineral</th>
<th>ZPM Products</th>
<th>Zinpro Recommendations Minimum Requirement ZPM, mg/kg diet</th>
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<tbody>
<tr>
<td>Zn</td>
<td>ZINPRO® Availa®Zn</td>
<td>60</td>
</tr>
<tr>
<td>Cu</td>
<td>CuPlex® Availa®Cu</td>
<td>40</td>
</tr>
<tr>
<td>Mn</td>
<td>MANPRO® Availa®Mn</td>
<td>40</td>
</tr>
<tr>
<td>Fe</td>
<td>Availa®Fe</td>
<td>50</td>
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<tr>
<td>Iª</td>
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<td>4</td>
</tr>
<tr>
<td>Seª</td>
<td>Availa®Se</td>
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</tr>
<tr>
<td>Crª</td>
<td>MiCroPlex® Availa®Cr</td>
<td>0.4</td>
</tr>
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</table>

ª Not a current ZPM source
ª Note upper limit allowed in EU is of 0.2 ppm, provided as organic source
ª Use where commercially available
Zinpro exists to improve the wellness and performance of animals and contribute to a healthier, more sustainable world.

Visit zinpro.com/aquaculture to learn more about the products available in your area.

Or contact your local Zinpro representative.