THE USE OF INEXPENSIVE SALT MIXTURES FOR INLAND, INTENSIVE SHRIMP (*LITOPENAEUS VANNAMEI*) FARMING

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USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Shrimp Production

- #1 Seafood Item in Most Developed Countries
- Most Shrimp are Imported
  - Trade Deficit
  - Food Safety (antibiotics/environmental toxins)
- Produce Shrimp Inland, Near Markets
  - Fresh, Never Frozen Possible
  - High Quality, Near Consumers
  - Healthy, Safe
  - Difficult to Acquire Otherwise
- High Demand = Higher Sale Price

Recirculating Aquaculture Systems (RAS)

- Closed systems
- Include Biofloc, Clear Water, & Hybrids of these
- Minimal H_20 exchanges
  - Salt and heat retention… marine animals inland!
- Environmentally safe… waste management
- High Biosecurity
- High animal densities
- Year-round production indoors → Tropical sp.
- Higher operational costs though…

Artificial Seawater Formulation

- Artificial Marine Sea Salt Mixes =

  Great, But Expensive
- Salinity: RAS > 10 g/L
- How About Home-Made Salt Formulations To Lower Costs?
  - Sure… But Be Careful!
- Recurring Problems: Deficiencies In Na, Mg, K, & Ca Along With Ionic Balances
- Formulation of Low Cost Alternative Sea Salt Mix Presents New Opportunities

Experimental Design

- Crystal Sea® Salt (CSS)
  - Standard, Complete Sea Salt Mix
- Least Cost Salt (LCS)

15 g/L Salt Solution @ $1m^3$	
NaCl	11,310 (g)
$MgSO_4$	1,830 (g)
$MgCl_2$	855 (g)
$CaCl_2$	376 (g)
KCl	240 (g)
$NaHCO_3$	90 (g)

5 Treatments

- 1.) **100% CSS**
- 2.) **75% CSS – 25% LCS**
- 3.) **50% CSS – 50% LCS**
- 4.) **75% LCS – 25% CSS**
- 5.) **100% LCS**
  - 20 – $1m^3$ tanks
  - 4 tanks per treatment
- Hybrid systems with external settling chambers and biofilter (MBBR)
- Salinity: 15 g/L for all tanks
- Density: 250 Shrimp/m^3

Management

- Duration: 84 days
- Initial Weight: 4.3 (g)
- Fed 3x Daily
- 2x Daily: Temperature, DO, pH, & Salinity
- 1x/Week: Ammonia (TAN), Nitrite (NO_2-N), and Turbidity (NTU)
- Final Data: Shrimp Production, Mineral Analysis

Statistical Analysis

- **Shrimp Production**
  - **One-way ANOVA**
- **Mineral Analysis**
  - **One-way ANOVA**
- **Water Quality**
  - **Repeated Measures ANOVA**

Water Quality

	Treatment				
	100% CSS	75% CSS	50% CSS/LCS	75% LCS	100% LCS
Temperature °C	27.7 ± 0.1 (25.2-28.7)	27.7 ± 0.1 (25.1-28.6)	27.9 ± 0.1 (25.3-28.7)	27.7 ± 0.1 (25.2-28.6)	27.7 ± 0.1 (25.2-28.7)
Dissolved Oxygen (mg L^{-1})	6.2 ± 0.0 (5.4-7.0)^{ab}	6.2 ± 0.0 (5.4-6.9)^{c}	6.2 ± 0.0 (5.4-6.8)^{bc}	6.2 ± 0.0 (5.5-6.8)^{a}	6.2 ± 0.0 (5.5-6.9)^{bc}
pH	7.9 ± 0.0 (7.7-8.3)^{a}	7.9 ± 0.0 (7.7-8.3)^{b}	7.9 ± 0.0 (7.7-8.3)^{b}	7.9 ± 0.0 (7.7-8.3)^{b}	7.9 ± 0.0 (7.7-8.3)^{b}
Salinity (g L^{-1})	15.1 ± 0.0 (14.6-15.7)	15.2 ± 0.0 (14.5-15.7)	15.2 ± 0.0 (14.4-15.8)	15.2 ± 0.0 (14.3-15.7)	15.2 ± 0.0 (14.8-15.7)
Ammonia (mg TAN L^{-1})	0.2 ± 0.1 (0.1-1.5)	0.2 ± 0.1 (0.1-1.0)	0.3 ± 0.1 (0.1-1.4)	0.2 ± 0.1 (0.1-1.0)	0.3 ± 0.1 (0.1-1.2)
Nitrite (mg NO_2-N L^{-1})	1.2 ± 0.4 (0.4-3.9)^{ab}	0.8 ± 0.1 (0.4-1.6)^{a}	1.2 ± 0.3 (0.4-3.6)^{ab}	0.9 ± 0.2 (0.4-2.0)^{ab}	1.2 ± 0.2 (0.5-2.3)^{b}
Turbidity (NTU)	32.1 ± 2.8 (18.7-48.8)	33.8 ± 3.2 (16.6-46.9)	30.1 ± 2.8 (15.0-40.7)	28.2 ± 2.2 (19.4-39.3)	32.6 ± 2.6 (19.4-42.44)

Minerals

Treatment

H_20	100% CSS	75% CSS	50% CSS/LCS	75% LCS	100% LCS
Na	5361 ± 471	5150 ± 353	5320 ± 399	5207 ± 433	5572 ± 440
Ca	99 ± 9	101 ± 11	109 ± 10	121 ± 12	126 ± 14
SO_{4-2}	1635 ± 88^{a}	1288 ± 41^{b}	1165 ± 27^{bc}	1163 ± 29^{bc}	974 ± 28^{c}
Mg	591 ± 51^{a}	520 ± 33^{ab}	477 ± 33^{ab}	430 ± 34^{ab}	411 ± 32^{b}
Sr	4.6 ± 0.4^{a}	4.0 ± 0.1^{ab}	3.8 ± 0.1^{ab}	3.6 ± 0.1^{b}	3.3 ± 0.3^{b}

Treatment

Tissue	100% CSS	75% CSS	50% CSS/LCS	75% LCS	100% LCS
Na	26117 ± 1429	28671 ± 1575	27655 ± 1277	27572 ± 1133	26453 ± 437
Ca	57883 ± 6205	63467 ± 9730	69160 ± 3374	71384 ± 1394	64731 ± 771
P	47276 ± 391^{ab}	52034 ± 2230^{ab}	52672 ± 574^{a}	47683 ± 1333^{ab}	46697 ± 898^{b}
K	24970 ± 598^{ab}	26363 ± 793^{a}	25487 ± 928^{ab}	23919 ± 717^{ab}	22682 ± 603^{b}

Shrimp Production

	Treatment				
	100% CSS	75% CSS	50% CSS/LCS	75% LCS	100% LCS
Average Weight (g)	22.9 ± 0.8	22.2 ± 0.5	22.4 ± 0.2	22.5 ± 0.6	22.5 ± 0.4
Growth rate (%)	1.6 ± 0.1	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.1	1.5 ± 0.0
FCR	1.8 ± 0.1	1.7 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	2.1 ± 0.2
Kg/m^{-3}	3.8 ± 0.2	3.9 ± 0.2	3.8 ± 0.3	4.0 ± 0.2	3.2 ± 0.3
Survival (%)	67.2 ± 3.8	70.3 ± 3.9	68.3 ± 5.2	73.1 ± 4.2	57.2 ± 6.2

- **No significant differences detected**

Salt Cost per Ingredient			Salt Cost per Formulation	
Items	$USD per $1m^{-3}$	$USD per/Kg	Treatment	$USD per $1m^{-3}$
NaCl (22.6 Kg)	$5.37	$0.42	100% CSS	$25.08
$MgSO_4$ (22.6 Kg)	$1.96	$0.95	75% CSS	$21.02
$MgCl_2$ (25 Kg)	$0.67	$0.70	50% CSS/LCS	$16.96
$CaCl_2$ (22.6 Kg)	$0.60	$0.77	75% LCS	$12.89
KCl (25 Kg)	$0.23	$0.86	100% LCS	$8.83
$NaHCO_3$ (22.6 Kg)	$0.01	$0.73		

- 100% CSS is 2.8x more expensive than LCS

Cost of Salt per Kg of Shrimp

Treatment	$USD
100% CSS	$6.66[a]
75% CSS	$5.50[a]
50% CSS/LCS	$4.57[b]
75% LCS	$3.20[c]
100% LCS	$2.87[c]

- 100% LCS & 75% LCS Significantly Less Cost/kg Than the Others
- 100% CSS is 2.3x More Expensive (per Kg of Shrimp) Than 100% LCS!

Follow Up Study… Low levels of CSS

- Treatments
  - 100% LCS
  - 97.5%/2.5% LCS/CSS
  - 95%/5% LCS/CSS
  - 90%/10% LCS/CSS
  - 80%/20% LCS/CSS
  - 75%/25% LCS/CSS
- Similar Design
- Same Systems/ Management
- Same Data Analysis
- Very Similar Results!
- No Significant Differences in Shrimp Production

Conclusions

- **No Effect (or Very Little) on Water Quality**
  - **Some inconsistent differences in DO, pH, and NO_2-N**
- **Some Differences in Mineral levels**
  - **$H_20 \rightarrow SO_4$, Mg, & Sr**
  - **Shrimp Tissue → P & K**

- **No Significant Differences in Shrimp Production**
- **Cost of Salt per Kg Shrimp < Half the Cost**

Future Investigations

- Determine if There are Effects of Salt Concentration (salinity levels)
- Long-Term Water Use Effects
- Effects of System Type
- Effects on Overall Production Economics

Thank You!

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