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Hidden value of feed: Water quality

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Recirculating aquaculture floc systems are very complex in nature

> Feed drives production performance as limited by the genetic profile of the shrimp but can also reduce results when feed waste products degrade the culture environment.

Feed is the primary driver in the success of recirculating aquaculture floc systems (RAFS) for shrimp. Feed drives animal performance as limited by the genetic profile of the shrimp. The major additions to RAFS water are shrimp and feed. Therefore, feed must also be the primary driver of water quality resulting from the metabolites excreted by the shrimp, the indigestible waste produced by the shrimp or the wasted feed from improper feeding practices.

Feed fate, chemical processes

When feed is consumed, digested, adsorbed and metabolized by the shrimp, waste by-products of these processes are excreted into the water. These include primarily ammonia and carbon dioxide. The ammonia, which is toxic to shrimp, is oxidized by the floc bacteria, converting it into nitrite (also toxic) and then into nitrate, which is much less toxic. Under aerobic conditions, the wasted feed and feces are converted to carbon dioxide and water by the floc bacteria. If anaerobic conditions are allowed to exist, another type of bacteria in the solid waste material can produce hydrogen sulfide, which is very toxic to shrimp.

Solid waste materials require proper management for RAFS to function properly. These solids, in addition to the solids resulting from excess floc, can be removed mechanically. Added probiotic bacteria can also be used to biodegrade most of these materials, but that creates more bacteria/floc in the system. Like the shrimp, the bacteria are living organisms that produce additional biomass while consuming oxygen and producing carbon dioxide as they grow and multiply.

On one hand, the bacteria are a positive necessity, because they remove toxic nitrogen compounds and digest solid waste materials. However, on the other hand, they have a negative effect by reducing water quality and potentially shrimp performance. With either method of waste remediation, there are associated costs.

Collectively, the chemical processes taking place in RAFS reduce pH and alkalinity, which is countered by the addition of sodium bicarbonate. The carbon dioxide produced by both the shrimp and bacteria can at higher levels produce an anesthetizing effect on the shrimp and create suboptimal pH that can suppress bacteria growth, while competing with the absorption of oxygen by the shrimp. Since optimum levels of oxygen are absolutely critical to achieve maximum metabolic efficiency in the system and the animals, oxygen supplementation is required through mechanical aeration or injection.

Relevant example

Researchers at the Texas A & M AgriLife Research Mariculture Laboratory at Flour Bluff in Corpus Christi, Texas, USA, recently published results from a trial they conducted comparing two feeds. This data can be used to demonstrate the theme of this article.

In the trial, a standard commercial feed (SCF-35) typically used in pond production and fed to shrimp stocked at 15 to 30 per square meter was compared to a high-density feed (HDF-35) specially formulated for intensive RAFS with stocking densities of 100 per square meter or greater. Both feeds contained 35 percent protein and 7 percent fat. Each feed was applied for 67 days to three 40-cubic meter RAFS raceways, each stocked at 500 per cubic meter with juvenile shrimp weighing 2.66 grams.

The primary production data are presented in Table 1. HDF-35 significantly outperformed SCF-35 in shrimp yield, average weight, growth rate and feed conversion, with the difference ranging 12 to 13 percent for the different parameters. These differences existed even though both feeds were formulated with 35 percent protein and 7 percent fat.

Feed affects performance

Normally, when evaluating studies of this type, the emphasis is placed on the primary production data, Table 1. However, in examining the importance of feed on water quality, which can both directly and indirectly affect shrimp performance and system economics, it should be noted that the HDF-35 treatment required 12.6 percent less feed to produce a unit of gain. For each kilogram of shrimp produced, 0.18 kg less feed was required. Accordingly, there would be proportionately less waste products and metabolites for the system to remove in some way.

Zeigler, Production summary, Table 1

	SCF-35	HDF-35	Difference
Yield (kg/m^3)	8.71	9.74	+ 1.03 (11.8%)*
Average weight (g)	19.74	22.12	+ 2.38 (12.1%)*
Growth (g/week)	1.76	2.03	+ 0.27 (15.3%)*
Feed-conversion ratio	1.43	1.25	- 0.18 (12.6%)*
Survival (%)	88.3	87.3	+ 1.00 (1.1%)

* Significant difference, P < 0.05.

Table 1. Production summary for 67-day growout study.

It would be assumed that considering the differences in feed-conversion ratio values, differences in water quality parameters would also be expressed (Table 2). There were indeed significant treatment effects on total suspended solids, volatile suspended solids and turbulence.

Zeigler, Water quality values, Table 2

Weekly Data		SCF-35 Mean	SCF-35 Minimum-Maximum	HDF-35 Mean	HDF-35 Minimum-Maximum
Alkalinity (mg/L)		171.00	102.00-230.00	208.00	123.00-274.00
Total suspended solids (mg/L)*		278.00	155.00-460.00	223.00	115.00-551.70
Volatile suspended solids (mg/L)*		205.00	116.70-287.50	161.00	92.00-435.00
Turbulence (NTU)*		125	67.9-246.0	90.00	45.7-132.0

Total ammonia nitrogen (mg/L)		0.26	0.10-0.51	0.22	0.08-0.49
Nitrite-nitrogen (mg/L)		0.47	0.10-1.22	0.40	0.06-2.24
Nitrate-nitrogen (mg/L)		136.00	45.54-285.71	140.00	39.53-358.72
Carbonaceous biochemical oxygen demand (mg/L)		37.00	14.50-62.80	37.00	10.40-69.50
Phosphate (mg/L)		10.00	0.28-21.06	9.00	0.52-16.37
Suspended solids (mg/L)		11.00	2.50-27.00	8.00	2.00-21.00
Daily Data	**Time**	**SCF-35 Mean**	**SCF-35 Minimum-Maximum**	**HDF-35 Mean**	**HDF-35 Minimum-Maximum**
Temperature (°C)	a.m.	29.50	28.06-30.47	29.60	27.46-30.71
	p.m.	30.30	28.81-31.54	30.46	28.23-31.59
Dissolved oxygen *mg/l)	a.m.	5.90	4.61-7.58	5.90	4.56-6.96
	p.m.	5.50	4.49-6.96	5.50	4.65-6.61
pH	a.m.	7.10	6.66-7.49	7.10	6.59-7.50
	p.m.	7.10	6.25-7.51	7.10	6.24-7.57
Salinity (ppt)		28.30	24.56-36.69	28.30	24.44-36.51

* Significant difference, P < 0.05.

Table 2. Water quality values for 67-day growout study.

Considering the higher values for these parameters for the CFS-35 treatment, one would predict higher levels of floc/bacteria in these raceways, which would increase carbon dioxide production and the requirement for oxygen and sodium bicarbonate supplementation to maintain optimum water quality standards. Also, it is assumed these conditions would be more stressful to the shrimp, as suggested by the differences in primary production parameters (Table 1).

Strong evidence for the correctness of these observations is presented in Table 3. The HDF-35 feed resulted in 11 percent less oxygen, 22 percent less sodium bicarbonate (even though it produced a higher alkalinity value) and 10 percent less water required. In addition, operating hours for the foam fractionators and settling tanks were reduced by 35 and 78 percent, respectively. These data all support the prediction of greater undigested solids and higher floc levels, which required removal at an associated cost.

Zeigler, Inputs and operating variables, Table 3

	SCF-35	HDF-35	Difference
Oxygen (m^3/kg shrimp)	0.73	0.65	- 0.08 (11%)
Sodium bicarbonate (kg)	53.6	41.6	- 12.0 (22%)

Water use (L/kg shrimp)	138.3	124.7	- 13.6 (10%)
Foam fractionators (hours)	1,253	812	- 441 (35%)
Settling tanks (hours)	392	87	- 305 (78%)
Molasses (L)	10	10	0

Table 3. Inputs and operating variables for 67-day growout study.

The HDF-35 reduced operating costs from improved water quality and thus would improve profitability. There is considerable opportunity for further feed improvements that could be achieved with additional exploration.

Perspectives

RAF systems are very complex in nature and involve numerous factors that are interrelated to system success and profitability. A total systems approach is required for effective decision making.

As research and commercialization of RAFS continue, consideration should be given to the following.
- Researchers should identify, track and report quantitatively and economically all input and operating variables associated with these systems.
- Large commercial projects should be constructed as a series of smaller independent modules so that through well-planned continuing trials, all input and operating variables can be tracked to determine cause-and-effect relationships for all line item costs and their respective effects on profitability.

Bottom Line: *Feed* drives water quality and related operating costs.

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