Evaluating Ingredients for Aquafeeds: Alternative Proteins for Trout Feeds

WESTERN REGIONAL AQUACULTURE CENTER

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TABLE OF CONTENTS

Photos
Front cover and above: Gary Fornshell

FIGURES

TABLES

INTRODUCTION

With the rapid rise in feed ingredient costs and the finite source of and growing demand for fish meal, alternative aquafeed ingredients are necessary to minimize feed costs.

When formulating feeds with alternative ingredients, nutritionists attempt to ensure that production parameters, such as growth rates and feed conversion ratios, are not detrimentally affected. Concomitant with higher inclusion levels and varieties of ingredients in a aquatic feeds, there is the pressing need to understand how these changes could negatively alter fish health and product quality.

For these reasons, interactive effects of nutrients and endogenous anti-nutritional compounds (i.e., trypsin inhibitor, gossypol, and glucosinlates—compounds that originate from within the ingredient) in the alternative feed ingredients require additional study. Specifically, increased

Photo: Ron Hardy

understanding of the amino acid needs of trout combined with data on the amino acid content and availability of commercially available alternative feed ingredients are necessary precursors to identifying appropriate ingredient combinations for cost-effective commercial diets that maintain fish growth, health, and product quality.

The objective of the Western Regional Aquaculture Center funded project, "Cost-effective, alternative protein diets for rainbow trout that support optimal growth, health and product quality," was to identify commercially available alternative ingredient combinations that meet the production needs of rainbow trout.

A good aquafeed starts not only with good ingredients, but also with a complete knowledge of the advantages and disadvantages of using each ingredient in a formulation. Many different sources and types of ingredients can be used, but nutritionists must know several things about each ingredient to determine the proper blend for a specific feeding purpose.

To fully evaluate an ingredient, a five-phase approach is applied to each candidate ingredient that includes compositional analysis, palatability, digestibility, functionality, and nutritional value assessed in feeding trials.

Determining the composition identifies the potential nutritional value, such as a high level of essential amino acids, or identifies potential liabilities, such as high crude fiber or ash content, that might limit an ingredient's value in feed formulation. This phase does not usually result in rejection of an ingredient, but may result in a decision to give the ingredient a lower priority ranking.

The second phase is to determine the effect of the ingredient on feed intake, or palatability of the diet. If an ingredient decreases feed consumption, the value of that ingredient is significantly reduced. Palatability enhancers can be added to overcome unpalatable ingredients, but this approach can be expensive. Also, reduced feed intake could be due to the presence of deleterious compounds (anti-nutrients) that are unacceptable.

The third phase is to determine the digestibility of the nutrients in the ingredient, i.e., how much of a nutrient in an ingredient can the fish actually digest and absorb. Some protein sources are highly digestible, such as fish meal and soy protein concentrate, but other ingredients, e.g., feather meal, can be very high in protein but low in available protein, depending on ingredient source. The digestibility of an ingredient will have a major impact on its economic value, but does not necessarily eliminate or elevate a particular ingredient, because minor differences in digestibility can often be adjusted for during diet formulation.

The fourth phase—functionality—involves evaluating the effect of the ingredient on the physical quality of the complete feed when it is pelleted. This is a very important aspect of the overall value of an ingredient to feed manufacturers.

The fifth and final phase involves fish feeding trials in which the ingredient is included, often across a range of levels (varying composition percentages), in experimental feeds, and during which growth performance is evaluated. These trials start as laboratory scale experiments and, when successful, expand to include pilot scale and then production studies conducted on commercial farms.

Nutrient composition results of ingredients evaluated during this WRAC project can be found at *http://ars.usda.gov/pacific-west-area/aberdeen-id/small-grains-and-potato-germplasm-research/docs/fish-ingredient-database/.*

The database titled, "Nutrient Digestibility of Fish Feed Ingredients," is a collaborative effort among the USDA-Agricultural Research Service Trout-Grains Project, Aberdeen and Hagerman, ID and Bozeman, MT, USDA-ARS H. K. Dupree Stuttgart National Aquaculture Research Center, and USDOI-Fish and Wildlife Service Bozeman Fish Technology Center.

Figure 1. The commercial trout facility in Idaho where experimental feed trials were conducted *Photo: Ron Hardy*

AQUAFEED EVALUATION EXPERIMENT

This technical report focuses on a production trial conducted on a commercial trout facility in Idaho (Figure 1), a product quality evaluation via sensory taste test panels, and a basic cost comparison analysis between the experimental feeds and a commercial control feed.

PRODUCTION TRIAL

Two experimental feeds were formulated based on previous laboratory results at the Bozeman Fish Technology Center. Alternative protein sources used for the trial were commodity feedstuffs readily available on the market. One experimental feed was plant protein based (PPD+) (Table 1) and the other was animal protein based (APD+) (Table 2) without fish meal. Both test diets were supplemented with the first three limiting amino acids (Lys, Met, Thr) on an ideal protein basis with respect to the amino acid profile of rainbow trout muscle. The two experimental feeds were compared to a commercial trout grower feed formulation (SPC) used routinely at the facility. The experimental feeds had less crude protein on an as-fed basis than the commercial feed, but all three had similar energy content (Table 3). All feeds were produced the same day at a commercial aquaculture feed manufacturing plant. The extruded pellets were 4.5 mm in size. Fish were fed as much as they would eat with demand feeders.

Approximately 3,100 rainbow trout per raceway were stocked into nine raceways in December 2012 (Table 4). Fish size at stocking averaged 2.1 fish per pound (218 g/fish). Raceway dimensions were 10 W × 35 L × 3 D feet.

Table 1. Feed formulation of plant protein based feed

Ingredient	PPD+ % dry weight basis	kg/MT as fed
Corn gluten meal 60%CP	21.00	216.115
Soy Protein Concentrate 68%CP	17.00	168.783
Soybean Meal 46%CP	15.00	159.631
Whole wheat	15.19	157.613
Poultry fat	11.04	103.390
Menhaden fish oil	8.00	74.920
Monocalcium Phosphate 21P	3.30	30.904
Lysine HCl	3.14	29.406
Lecithin, Alcolec-S Liquid	1.00	9.365
Choline Cl 50%	1.00	9.365
DL-Methionine	0.72	6.743
Stay-C 35	0.15	1.405
Astaxanthin	0.045	0.425
Vitamin premix ARS 702	1.00	9.365
Threonine	0.81	7.586
Taurine	0.50	4.682
BioFix Plus	0.10	0.936
Potassium chloride	0.56	5.244
NaCl	0.28	2.622
TM ARS 640	0.10	0.936
Magnesium Oxide	0.06	0.562
	100.00	1000.00

Raceways received on average approximately 606 gallons per minute each of third-use 58°F (14.5°C) spring water, providing 4.6 exchanges per hour throughout the 125-day trial (Figure 2).

Each month, in addition to monthly inventory and daily mortality removal, 60 fish per raceway were sampled for length and weight frequencies. Ten additional fish per raceway were removed for proximate composition (five fish), and dress-out, fillet yield, visceral index, and hepato-somatic index (five fish).

Growth is the response variable measured in most nutrient utilization studies and is defined as live-weight gain, i.e., the difference between initial (W_i) and final (W_f) live weights and is usually expressed in grams. Live-weight gain is sometimes reported as a percent gain that is live-weight gain divided by the initial weight multiplied by 100 as follows:

$$\text{Weight gain (\%)} = \left[\frac{W_f - W_i}{W_i}\right] \times 100$$

Three additional commonly used growth rate calculations are daily gain (DG), daily growth coefficient (DGC), and specific growth rate (SGR). Daily gain—grams of live weight gained per day—is probably the most practical of the three growth metrics and is calculated as follows:

$$DG = \left[\frac{W_f - W_i}{t}\right]$$, where t = time, usually expressed as days.

Daily growth coefficient is the difference in the third-roots of the final and initial live weights over time on a percent basis as follows:

$$DGC = \left[\frac{W_f^{1/3} - W_i^{1/3}}{t}\right] \times 100$$

Specific growth rate is the difference of the natural logs of the final and initial live weights over time expressed on a percent basis as follows:

$$SGR = \left[\frac{\ln W_f - \ln W_i}{t}\right] \times 100$$

Both DGC and SGR are relative values that are most useful when compared to data from other groups of fish grown at the same temperature.

Examples

Given a group of trout with an initial live-weight of 10 grams and final live-weight of 400 grams after 140 days, the daily growth, daily growth coefficient and specific growth rate are as follows:

$$\text{Daily Growth} = \frac{(400\,g - 10\,g)}{140\ days} = 2.79\ g/day\ gain$$

$$\text{Daily Growth Coefficient} = \left[\frac{400\,g^{1/3} - 10\,g^{1/3}}{140\ days}\right] \times 100 = 3.72$$

$$\text{Specific Growth Rate} = \left[\frac{\ln 400\,g - \ln 10\,g}{140\ days}\right] \times 100 = 2.63$$

Table 2. Feed formulation of animal protein based feed

Ingredient	APD+ % dry weight basis	kg/MT as fed
Poultry by-product, pet food	24.00	242.841
Whole wheat	20.00	206.200
Soybean Meal 46%CP WRAC	11.71	123.872
Corn gluten meal 60%CP	8.60	87.974
Poultry fat	8.12	75.588
Menhaden fish oil	8.00	74.471
Wheat middlings	3.04	31.836
SC Blood 13	3.00	29.650
Feather meal 2007	3.00	29.543
Lysine HCl	2.87	26.717
Monocalcium Phosphate 21P	1.30	12.102
Lecithin, Alcolec-S Liquid	1.00	9.309
Choline Cl 50%	1.00	9.309
DL-Methionine	0.72	6.702
Stay-C 35	0.15	1.396
Astaxanthin	0.045	0.372
Vitamin premix ARS 702	1.00	9.309
Threonine	0.85	7.913
Taurine	0.50	4.654
BioFix Plus	0.10	0.931
Potassium chloride	0.56	5.213
NaCl	0.28	2.606
TM ARS 640	0.10	0.931
Magnesium Oxide	0.06	0.559
	100.00	1000.00

Table 3. Nutrient and energy formulation targets (dry weight basis) and analyzed nutrient composition as fed

Formulation targets[1]	PPD+	APD+	SPC
		% dry wt basis	
Crude protein	40.40	40.16	
Lipid	20.00	20.00	
Digestible protein	38.05	37.32	
Digestible Energy - kJ/kg	19.32	19.27	
Total P	1.07	1.01	
Available -P	0.53	0.52	
Digestible amino acids			
Arg	2.33	2.36	
His	0.76	0.86	
Ile	1.43	1.43	
Leu	4.04	3.58	
Lys	3.81	3.82	
Met	1.30	1.30	
Phe	2.01	1.84	
Thr	2.14	2.14	
Val	1.70	2.02	
Analyzed composition	**PPD+**	**APD+**	**SPC**
		% as-fed basis	
Crude protein	38.7	40.0	45.6
Fat	20.5	14.2	16.9
Energy kJ/kg	21.8	21.45	21.8
Alanine	2.11	2.41	2.85
Arginine	1.94	2.23	2.65
Aspartic	3.27	3.23	4.19
Cystine	0.52	0.54	0.7
Glutamic	7.04	6.04	6.18
Glycine	1.34	2.76	3.07
Histidine	0.84	0.94	1.42
Isoleucine	1.53	1.41	1.62
Leucine	3.89	3.49	4.12
Lysine	3.73	3.79	2.97
Methionine	1.27	1.21	0.91
Phenylalanine	1.94	1.83	2.30
Proline	2.42	2.65	2.74
Serine	1.83	1.94	2.56
Taurine	0.52	0.66	0.17
Threonine	2.13	2.28	1.80
Tryptophan	0.40	0.43	0.56
Tyrosine	1.31	1.11	1.28
Valine	1.68	1.96	2.7
Total amino acids	39.71	40.91	44.88

[1] PPD+ plant protein based feed, APD+ animal protein based feed, SPC commercial trout grower feed

Table 4. Stocking rates and density of rainbow trout at the start of the feeding trial

Raceway	Fish number	Fish size (fish/lb)	Raceway biomass (lb)
1	3079	1.92	1607
2	3079	1.92	1602
3	3142	2.05	1532
4	3176	2.20	1447
5	3026	1.96	1545
6	3083	2.22	1388
7	3049	2.17	1403
8	3049	2.27	1342
9	3083	2.08	1481

Accurate assessment of feed intake by fish is difficult, but it is crucial to measure feed intake as part of the feed ingredient evaluation process. Feed intake is usually reported as both an amount (gram feed/fish) and rate (gram feed/fish/day). The efficiency of feed intake by fish is reported either as the feed conversion ratio (FCR) or feed efficiency (FE).

$$\text{Feed Conversion Ratio (FCR)} = \frac{\textit{amount feed fed}}{\textit{fish weight gain}}$$

$$\text{Feed Efficiency (FE)} = \frac{\textit{fish weight gain}}{\textit{amount feed fed}}$$

Nutritionists often use FE, and a high value indicates greater efficiency of feed consumed being converted into growth, whereas with FCR the lower the value the more efficient the conversion of feed into weight gain.

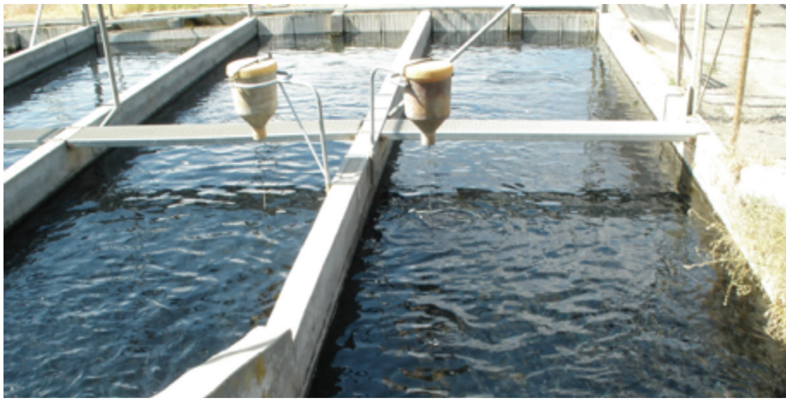

Figure 2. Raceways used for the production trial

Photo: Gary Fornshell

FISH PERFORMANCE

After 125 days, fish were harvested and transported to a processing plant. Fish performed equally well on all three feeds (Figures 3 & 4); there were no statistical differences in fish growth, feed conversion ratio, or survival between diets (Table 5). However, overall performance for all three treatments was lower than expected for this particular commercial cooperator. A number of contributing factors may explain the decreased performance. During the course of the production trial, a disease outbreak affected fish in all nine raceways. The presumptive diagnosis based on observed symptoms and previous disease episodes at the facility was bacterial coldwater disease caused by *Flavobacterium psychrophilum*. The third-use raceways

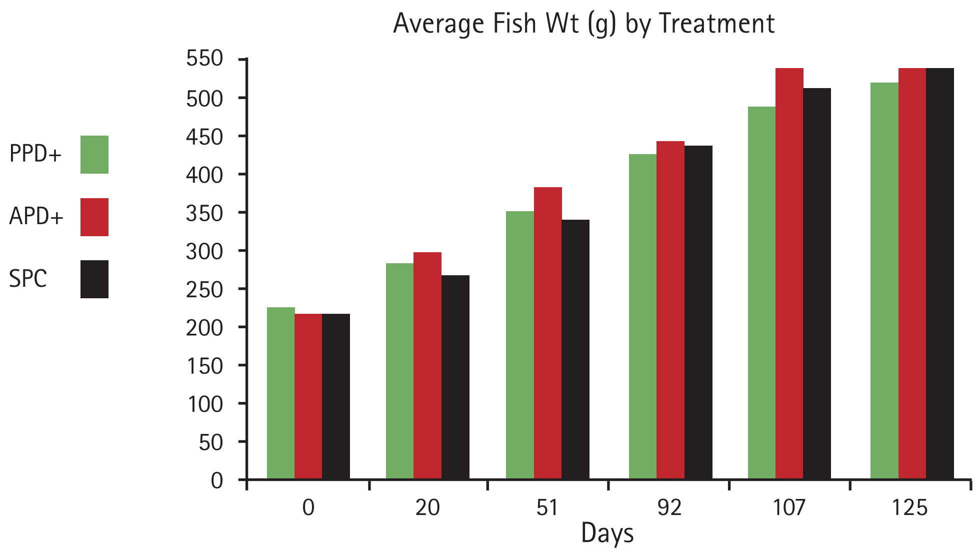

Figure 3. Comparison of average weight of fish fed three diets during a 125 day feeding trial. PPD+, plant protein diet with reduced digestible protein and supplemental amino acids. APD+, animal protein diet, with no fish meal, and reduced digestible protein and supplemental amino acids. SPC, commercial control diet

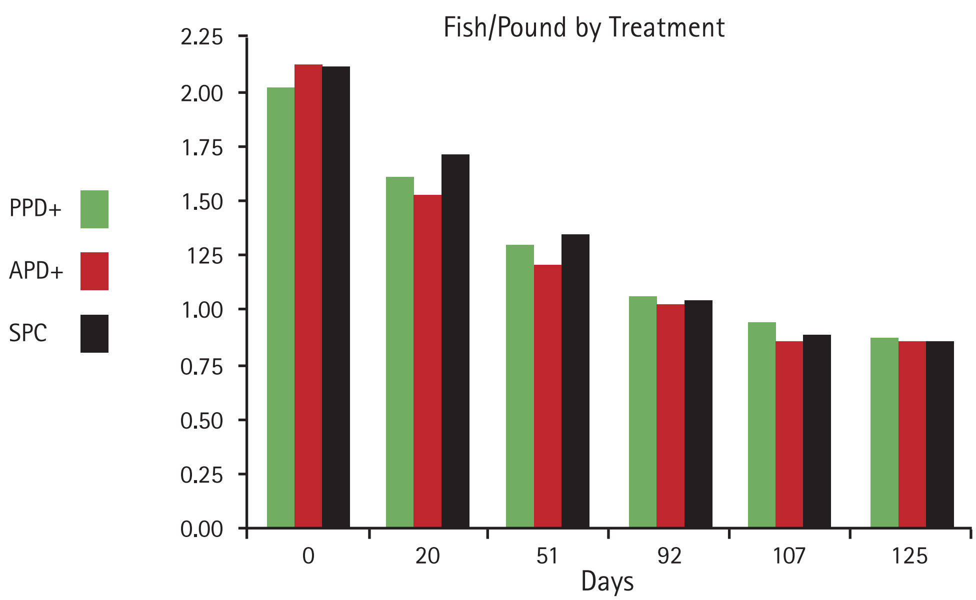

Figure 4. Comparison of the number of fish per pound fed three diets during a 125 day feeding trial. PPD+, plant protein diet with reduced digestible protein and supplemental amino acids. APD+, animal protein diet, with no fish meal, and reduced digestible protein and supplemental amino acids. SPC, commercial control diet

Table 5. Growth rate, feed conversion ratio and survival (%) of rainbow trout fed plant protein, animal protein and a commercial control diet for 125 days

Feed	(g/day)[1]	SGR[2]	DGC[3]	FCR[4]	S[5]
PPD+	2.37	0.67	1.57	2.4	68
APD+	2.57	0.73	1.71	2.3	70
SPC	2.61	0.74	1.73	2.1	71

[1] g/day, grams of weight gained per fish per day
[2] SGR, specific growth rate, $[(\ln W_f - \ln W_i)/t] \times 100$
[3] DGC, daily growth coefficient, $[(W^{1/3}_f - W^{1/3}_i)/t] \times 100$
[4] FCR, feed conversion ratio
[5] S, percent survival

also regularly received cleaning effluent from up-stream tiers of raceways constituting first and second use. Finally, spring flows declined as the trial progressed, so that fish were being feed as water flows diminished.

The daily gain (g/day) of fish fed PPD+, APD+, and SPC during the commercial on-farm feeding trial were 2.37, 2.57, and 2.61, respectively. These are substantially lower than the daily gains of 5.41, 5.75, and 6.23, for PPD+, APD+, and SPC, respectively observed at the Bozeman Fish Technology Center laboratory trial under less stressful conditions and slightly warmer water (59°F/15°C). In contrast, a yield verification study (280 days) conducted at the commercial facility in 2004/2005 determined a daily gain of 4.62.

Feed conversion ratios for the trial were higher than what is typical for trout raceway culture (1.2) and were 2.4, 2.3, and 2.1 for PPD+, APD+, and SPC, respectively.

These are substantially higher than the FCRs of 0.94, 0.93, and 1.02, for PPD+, APD+, and SPC, respectively observed at the Bozeman Fish Technology Center laboratory trial. Survival was also lower than expected; 68%, 70%, and 69% for fish fed PPD+, APD+, and SPC, respectively, for the reasons mentioned previously.

PRODUCT QUALITY

Changes in diet composition are known to influence product quality. Previous research has suggested that plant proteins alter fillet composition and post-mortem physical characteristics of fillets including color and oxidative stability. Plant proteins may also alter dress-out and fillet yield.

In our production trial, diet did not significantly alter whole body composition; moisture, protein, lipid, and energy were essentially the same among fish from the three treatments (Table 6). Visceral and hepatosomatic index as well as dress-out and fillet yield were not affected by diet.

Table 6. Whole fish moisture, protein and fat concentration at the end of the 125-day feeding trial

DIET	Moisture	Protein %	Fat
PPD+	62.6	17.2	18.0
APD+	63.9	16.2	18.4
SPC	65.1	17.5	16.5

One notable fillet quality difference among dietary treatments was color, even though astaxanthin was added to all feeds. Trout fed PPD+ had a lighter and more orange fillet color compared to trout fed APD+ and SPC. Field-based visual color assessments using a SalmoFan™ found fillet readings of 22–24, 28–30, and 28–31 for PPD+, APD+, and SPC, respectively. Values range from 20 for light pink to 34 for dark red on the SalmoFan™ color scale. Fillet color assessment was also performed on fish from the study conducted at the Bozeman Fish Technology Center using a Minolta color reader. The color reader measured three color attributes: L* represents lightness (0 = black, 100 = white), a* represents the intensity of the color red, and b* represents the intensity of the color yellow. The fillets from trout fed PPD+ had significantly higher readings of lightness and yellow color intensity, and lower red color intensity. The fillets of trout fed the fish meal-based SPC had significantly greater intensity of the color red. Fillet color among the dietary treatments was similar between the commercial and Bozeman trials, with the trout fed PPD+ having a lighter and more orange color and the trout fed APD+ and SPC having a darker more red color (Figure 5).

Corn gluten meal in the feed is known to impart color attributes to salmonid fillets, including rainbow trout. To prevent these impacts, inclusion levels of corn gluten meal in commercial trout feeds are generally kept at less than 9% of the diet to prevent suboptimal muscle pigmentation and subsequent suboptimal fillet color for fish intended for

Figure 5. Fillet color of rainbow trout fed animal protein diet, commercial trout diet (control) and plant protein diet at Bozeman Fish Technology Center *Photo: Wendy Sealey*

sale in the white fillet market. It appears that the adverse effects on fillet color could not be masked with astaxanthin in the current trial that included 21% corn gluten meal in the plant-based diet.

SENSORY EVALUATION

Fish from the production trial were processed at a commercial fish processing plant. Fillets for sensory evaluation were frozen and shipped on dry ice to the Washington State University School of Food Science Sensory Facility. Sample of trout fillets were included from each diet treatment and from all three raceways within each treatment. Serving portions of approximately 10 g each were sliced across the skinless fillets from dorsal to ventral. The portions were vacuum packed in boil-in pouches. The vacuum packaged samples were poached at 165° F for six minutes, removed from the pouches and placed under radiant heat for no longer than 15 minutes.

Seventy-three untrained consumers (panelists) were recruited from the surrounding area. The majority of consumers ate fish at least once per month. They ranged in age from 18 to 61 and were from diverse racial and ethnic backgrounds. Approximately 46% (34 of 73) were female.

Prior to being served, each poached fillet sample was transferred from the radiant warmer to 6-inch paper plate. Consumers were provided with filtered water and unsalted-top crackers for rinsing the palate. A cuspidor was provided for expectoration.

The method of evaluation was the directional paired difference test. Following a series of demographic questions, panelists were presented with sample pairs 1) APD+ vs SPC, 2) PPD+ vs SPC, and 3) PPD+ vs APD+ in three flights. Samples were labeled with 3-digit codes and pairs were presented in random order. Panelists were asked to indicate which sample in a pair had more: 1) fishy aroma, 2) fishy flavor, 3) grassy flavor, and 4) firm texture. Panelists were also asked to indicate which sample in a pair they preferred. Panelists were given the opportunity to comment on why they preferred a specific sample.

Panelists indicated a significantly greater grassy flavor with APD+ in a paired comparison with SPC, but no preference of one over the other. Comparing PPD+ and SPC, panelists indicated a significantly more fishy aroma and fishy flavor with SPC and firmer texture with PPD+. Overall, they preferred SPC over PPD+. In another set of comparisons, APD+ had a significantly more fishy aroma and flavor compared to PPD+ and PPD+ had a firmer texture compared to ADP+. There was no significant preference between the two experimental diets.

The panelists were able to distinguish between diets in various sensory attributes. However, regardless of comparison, all diets produced fillets that were preferred by some people. The only significant preference was that of SPC over PPD+. At a workshop with trout producers (22) the same sensory evaluation was conducted. The one significant difference was that fillets from fish fed the SPC diet had a more fishy aroma compared to those fed PPD+.

Sensory evaluation also included smoked fillets from trout fed the three different diets. Trout fillets were smoked at the same commercial processing facility. Smoked fillets were vacuum packed and shipped overnight on ice. Serving portions of 10 g were sliced across the fillet from dorsal to ventral, trimming the sample to select the thickest part of the fillet. The skin was removed. Samples were served in 4 oz. portion cups labeled with a random code and sealed with a cap to trap the aroma. Samples were served at room temperature.

Panelists (84) were presented with sample pairs 1) APD+ vs SPC, 2) PPD+ vs SPC, and 3) PPD+ vs APD+ in three flights. Samples were labeled with 3-digit codes and pairs were presented in random order. Panelists were asked to indicate which sample in a pair had more: 1) smoked aroma, 2) fishy aroma, 3) smoked flavor, 4) fishy flavor, 5) salty taste, 6) firm texture, and 7) moist texture. Panelists were also asked to indicate which sample in a pair they preferred based on color and on overall preference. Panelists were given the opportunity to comment on why they preferred a specific sample.

SPC had a more fishy aroma and salty taste compared to APD+, but there was no difference in preference for color or overall preference between the two. SPC had a more smoky aroma and was preferred for color compared to PPD+, but no overall preference was found between the two diets. APD+ had a more preferred color than PPD+, but no overall preference was found between the two. At a workshop with trout producers (22) the same sensory evaluation with smoked trout was conducted. Trout producers found the APD+ diet resulted in smoked trout with a more smoky aroma when compared to the smoked trout fed the PPD+ diet. They preferred the color of both the SPC and APD+ smoked trout over the PPD+ smoked trout. Panelists who preferred the color of the SPC and APD+ fillet over the color of the PPD+ fillet described the preferred sample as darker, redder, more pink, and "healthier" in appearance. The color of the PPD+ fillet was rejected as being more grey, yellow, or pale.

Product quality is a complex function of raw material characteristics and extrinsic factors such as freshness, pre- and post-harvest handling procedures. Important intrinsic quality traits are color, texture, processing characteristics, fat content, and chemical composition of the muscle. Consumers perceive the pink-red hue of the muscle of salmonids, particularly salmon, as superior flesh quality and have a greater willingness to pay for it. The carotenoid pigments in the feed account for 6–8% of total production costs. Color, therefore, is an important economic quality trait because of the cost to the producer in comparison to the consumer's willingness to pay. Suboptimal muscle pigmentation such as lighter or uneven color can significantly reduce the economic value of fillets by up to 40% at processing plants. Anecdotally, according to the manager of the processing plant employed in this study, the color of the PPD+ fillets without comparison to the SPC and APD+ fillets was acceptable. However, once displayed together in a seafood case the suboptimal coloration of the PPD+ fillets is readily apparent.

The only significant preference of the sensory evaluations was for the poached SPC sample over the poached PPD+ sample. The SPC sample had more fishy flavor and aroma, while the PPD+ sample was firmer. Sensory evaluation of trout fed either a fish meal based feed or an all plant protein based feed in a study conducted in France for 24 weeks found that the flesh of the trout fed the plant protein feed had higher hardness, less sweetness, less odor intensity and a trend toward lower juiciness than the flesh from trout fed the fish meal feed. Juiciness is an important contributor to eating quality although the relationship between juiciness and the objective measurement of it is not completely clear. Perhaps the firmer texture of the PPD+ fillet resulting in less juiciness contributed to the increased preference of the SPC fillet.

FEED COST COMPARISON

Feed costs account for a significant portion of operating expenses for trout producers, ranging from 40 to 60% of operating expenses. Producers therefore have a strong incentive to optimize feed efficiency.

Example

Assume a feed cost of $0.70/lb, an FCR of 1.2, and 100,000 pounds of production. Feed cost per pound gain (FCR × cost of feed per pound) can be used to illustrate the effect of FCR on feed costs (Figure 6). In this example, an increase of 0.1 in FCR results in a $7,000 increase in feed costs.

To compare the costs of the three feeds used in the production trial, return over feed cost was calculated using feed cost per pound gain and a range of trout prices received (low, medium, and high). Feed cost for the experimental feeds was determined by providing the formulas to feed manufacturers to obtain the costs, and then averaging their responses. Feed costs were based on bulk feed. The control feed (SPC) cost was obtained from the feed manufacturers' price list at the same time. Prices per pound of trout were determined by surveying producers in the area and the range for low, medium, and high was based on market white fillet, market red fillet, and large red fillet, respectively.

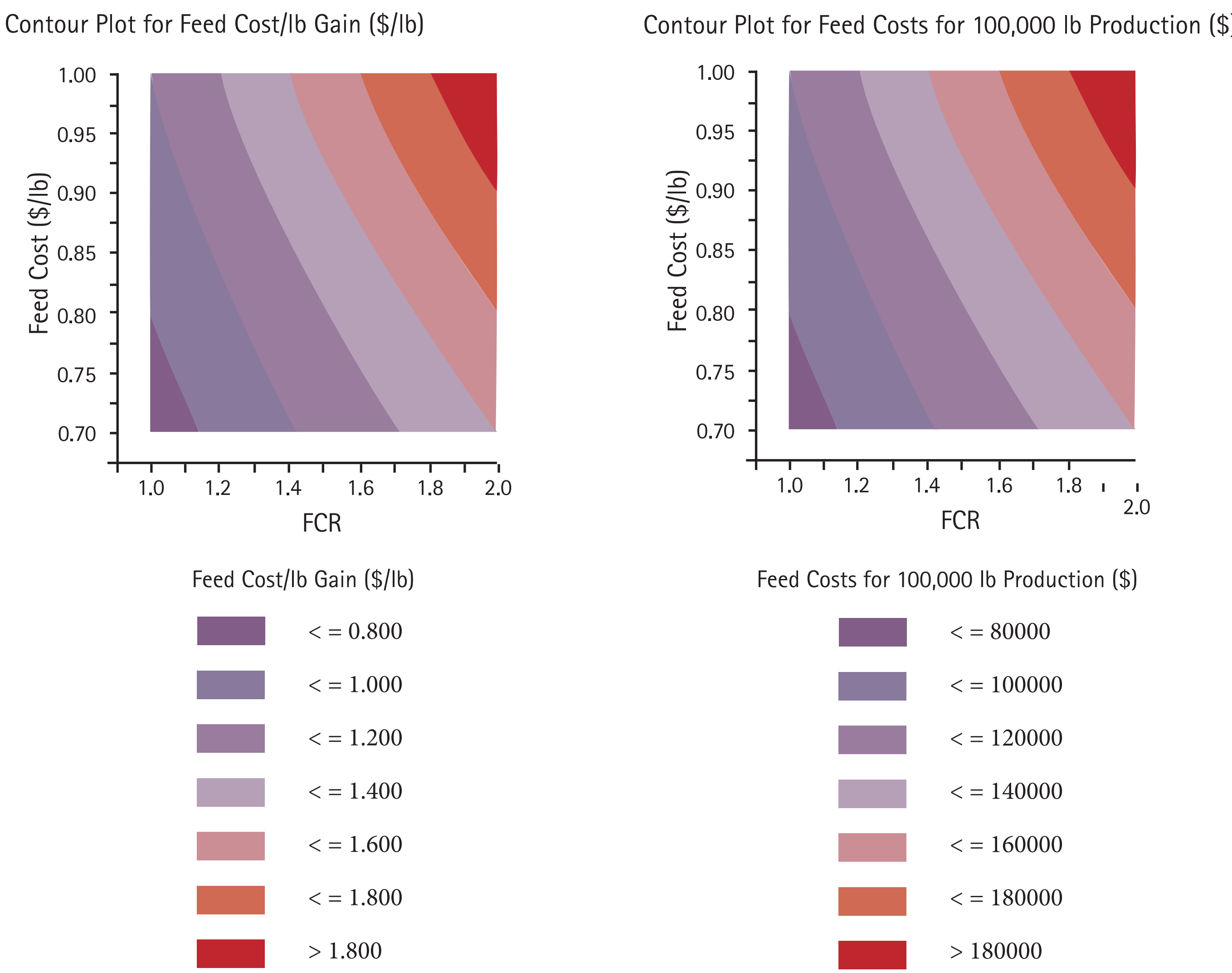

Figure 6. Contour plots for feed costs

Based on results from the production trial, return over feed costs for all three feeds at low, medium, and high prices received resulted in negative returns. This was obviously the result of higher than normal FCRs. However, when a typical FCR of 1.2 was used for the three feeds and compared to a medium trout price received, returns over feed cost for PPD+, APD+, and SPC were $0.425/lb, $0.463/lb, and $0.462/lb, respectively. The all animal protein feed compares quite well with the control feed. Because ingredient costs fluctuate over time, how one feed compares to another may change over time. A second cost comparison conducted one year after the initial comparison resulted in cost reductions for both experimental feeds. The initial difference between PPD+ and APD+ was about $64.00 per ton, yet one year later the difference was only $1.30 per ton.

Feed cost per pound gain is a useful metric to compare various feeds relative to cost and efficiency. Purchasing the least expensive feed is not necessarily the most cost-effective option. A more expensive feed with a lower FCR can be more cost-effective than a less expensive feed. Given the rapid rise in feed ingredient costs and the finite supply of fish meal, alternative aquafeed ingredients are necessary to minimize feed costs. However, when formulating feeds with alternative ingredients one must ensure that growth rate, feed conversion ratio, fish health, and product quality are not detrimentally affected.

SUMMARY

This technical report describes the evaluation of two experimental feeds with alternative ingredients and one commercial control feed during a production trial at a commercial trout facility in Idaho (Figure 7). In addition to the usual production metrics measured, product quality was evaluated using taste test panels, and a basic cost comparison analysis was conducted.

The fish fed the plant protein and the animal protein feeds without fish meal performed equal to the commercial fish meal based feed based on growth rate, feed conversion ratio, and survival and demonstrate that total protein can be reduced from 45% to approximately 40% crude protein (38% digestible protein) without affecting growth rate when amino acid targets are met. This is important because protein is typically one of the most expensive nutrients in aquafeeds.

One notable difference in production due to feed was fillet color. Fillet color is an important product quality trait affected by pigments in some feed ingredients; thus, consideration must be given to the appropriate levels of corn gluten meal in aquafeeds for rainbow trout in order to increase the usage of plant-based feeds by farmers. Similarly, the feed cost comparison indicated that the experimental feeds were comparable to the control commercial feed in cost-effectiveness; however, because feed ingredient costs fluctuate over time, how one feed compares to another may change. These results taken together demonstrate that alternative protein diets can be commercially viable for rainbow trout commercial production when the noted caveats are addressed.

Figure 7. From left to right: plant protein diet, animal protein diet, and commercial trout diet

Photo: Wendy Sealey

Measuring fish growth using length *Photo: Chris Myrick*

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