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Meat and Bone Meal as a Major Dietary Ingredient for Salmonids Under Several Growth Regimes

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INDUSTRY SUMMARY

INTRODUCTION:

Aquaculture production of trout and salmon is expected to drastically increase during the next two decades. Fish meals are a good source of protein and energy for salmonids and comprise approximately 50 % of the content of all diets used in trout and salmon production. The current increasing demand for fish meal for purposes outside fish feeds has increased its price and may make it impractical for use in the very near future. Furthermore, the recent ban on using meat and bone meal derived from domestic animals for ruminant feeds has created additional markets for this product. If meat and bone meal can replace part or all of the fish meal normally used in trout and salmon diets, it would be of considerable economic benefit to the users and the producers of this product. The current cost of meat and bone meal is approximately 45 % that of fish meal. The price differential would substantially decrease the cost of fish diets, and the added increased use of meat and bone meal would bring about the benefits of an expanded market for the manufacturers of this product. A thorough evaluation of meat and bone meal as a replacement dietary ingredient for fish meal is needed to assess the feasibility of its adoption into the aquaculture industry.

OBJECTIVES:

The objective of this project was to evaluate the nutritional value of meat and bone meal as a replacement for fish meal in the diets of cultured salmonids under two growth regimes (with and without the administration of bST (bovine somatotropin). This work was conducted with

rainbow trout since they are a representative of the salmonid family and an important species in the aquaculture industry. The specific objectives were:

1. To determine the nutritional value of meat and bone meal as a replacement for fish meal in diets for rainbow trout growing during the production-size phase.

2. To determine the nutritional value of supplemental amino acids used in conjunction with meat and bone meal as a replacement for fish meal.

3. To determine the extent to which bST improves the efficiency of protein utilization from meat and bone meal.

4. To determine the availability of phosphorus in meat and bone meal and assess phosphorus in aquacultural effluent.

SUMMARY:
Feeding experiments which examined the potential of replacing fish meal protein with a standard, good quality, meat and bone meal protein indicated that fish meal protein can be replaced with 25 to 50 % meat and bone meal protein with only 5 to 10 % loss in feed/gain, and up to 75 % with a 15 % loss in feed/gain. Body composition results of this study indicated that there were no differences ($P > 0.05$) in dry matter and protein content of the whole body carcass fed the dietary treatments. Results also indicated that there was an increase ($P < 0.05$) in carcass fat with the addition of standard meat and bone meal at 25 % and 100 % when compared to the control diet (100 % fish meal and 0 % meat and bone meal) (D100:0). It is not clear why carcass fat did not increase when standard meat and bone meal was added at 50 and 75 %. However, only a sub-sample of each treatment group was analyzed and it may be that the number of fish used to determine body composition was too small to detect a difference.

Subsequent feeding experiments which examined the potential of replacing fish meal protein with low ash meat and bone meal protein indicated that fish meal protein can be replaced with 25 to 50 % low ash meat and bone meal protein with only a 5 to 10 % loss in feed/gain, and up to 75 % with a 20 % loss in feed/gain. Body composition results of this study indicated that dry matter and protein content of the whole body carcass decreased ($P < 0.05$) while ash and fat content increased ($P < 0.05$) with increasing amounts of low ash meat and bone meal. The deposition of more fat and less total carcass protein may reduce the overall carcass dressing percentage on whole fish and this would be a major concern to the aquaculture industry. Future studies examining the replacement of fish meal with low ash meat and bone meal must address this concern.

Feeding experiments which examined the nutritional value of supplementing the amino acids tryptophan, methionine, and lysine (TML) in conjunction with meat and bone meal as a replacement for fish meal with and without bST indicated that the addition of these amino acids had no effect ($P > 0.05$) on improving growth performance when fish meal protein was replaced with 75 % low ash meat and bone meal protein. Feeding experiments which examined the potential of replacing fish meal protein with low ash meat and bone meal with bST (120 µg/g BW/3 wks, Posilac©) indicated that bST in addition to the control diet (D100:0) increased gains

70 % and improved feed efficiency approximately 15 % when compared to the D100:0 diet. Using the bST + D100:0 diet as the control diet and comparing it to the two diets that received bST + D25:75 (25 % fish meal and 75 % low ash meat and bone meal) with and without the addition of the amino acids T, M, and L, it appeared that without the supplementation of these amino acids, fish gain was decreased ($P < 0.05$) by approximately 20 %. It also appeared that feed efficiency was reduced ($P < 0.05$) 5 and 10 % with the supplementation of amino acids (bST + D25:75 + TML) and without the supplementation of amino acids (bST + D25:75). It is clear that with the supplementation of the amino acids (T, M, and L) to diets containing 75 % low ash meat and bone meal, there is no benefit on improving growth performance in rainbow trout. However, under an accelerated growth regime (the use of bST), these amino acids seemed to play a positive role in fish gain. It also appeared that bST has little to no effect on improving the efficiency of protein utilization with low ash meat and bone meal.

Effects of replacing fish meal protein with meat and bone meal protein as a major dietary ingredient on growth performance in rainbow trout (Oncorhynchus mykiss).

G.T. Schelling, M.T. Casten, N.J. Hughes, R.A. Roeder, and R.W. Hardy; University of Idaho, Moscow, ID, USA.

Abstract:

Feeding experiments were conducted to examine the potential of replacing fish meal protein (FM) with a standard, good quality meat and bone meal protein (MBM) in 25 % increments for growing rainbow trout. With the objective of making an overall evaluation of growth performance and carcass composition, semi-purified diets were used to provide FM protein:MBM protein of 100:0, 75:25, 50:50, 25:75, and 0:100 as the sole dietary protein in isonitrogenous and isocaloric diets. Two hundred and twenty five rainbow trout (mean weight 120 g) were allotted to five treatments with three replicates in a randomized block design. The tanks were five cubic feet; water flow = 20.51 L/min; temperature = 15°C. The fish were hand fed to satiation twice daily and were weighed on d 0, 21, 42, and 63. Daily gain, daily feed intake, and feed/gain ratios were determined for growth performance. A sub-population of fish were sacrificed on d 63 for body composition determination by whole carcass proximate analysis. In the 100:0 diet, fish gained 3.8 g/d and the relative percentage gains for the series of diets with increasing MBM protein were 100, 90, 83, 85, and 59 % (59 lower, $P < 0.05$). The feed/gain ratios were .94, .98, 1.04, 1.09 and 1.46 (1.46 less efficient, $P < 0.05$), respectively. There were no marked differences ($P > 0.05$) in dry matter and protein content of the whole body carcass fed the dietary treatments. The 0:100 diet resulted in reduced growth ($P < 0.05$) and therefore, had somewhat more carcass fat. This work indicates that FM protein in semi-purified diets for rainbow trout can be replaced with 25 and 50 % MBM protein with only 5 and 10 % loss in F/G, and even up to 75 % with a 15 % loss in F/G.

Key words: Meat and bone meal protein, Fish protein nutrition, Rainbow trout

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Effects of replacing fish meal protein with low ash meat and bone meal protein as a major dietary ingredient on growth performance in rainbow trout (Oncorhynchus mykiss).

G.T. Schelling, M.T. Casten, N.J. Hughes, R.A. Roeder, and R.W. Hardy;
University of Idaho, Moscow, ID, USA.

Abstract:
Feeding experiments were conducted to examine the potential of replacing fish meal protein (FM) with a standard, good quality, low ash meat and bone meal protein (LAMBM) in 25 % increments for growing rainbow trout. With the objective of making an overall evaluation of growth performance and carcass composition, semi-purified diets were used to provide FM protein:LAMBM protein of 100:0, 75:25, 50:50, 25:75, and 0:100 as the sole dietary protein in isonitrogenous and isocaloric diets. Two hundred and twenty five rainbow trout (mean weight 120 g) were allotted to five treatments with three replicates in a randomized block design. The tanks were five cubic feet; water flow = 20.51 L/min; temperature = 15°C. The fish were hand fed to satiation twice daily and were weighed on d 0, 21, 42, and 63. Daily gain, daily feed intake, and feed/gain ratios were determined for growth performance. A sub-population of fish were sacrificed on d 63 for body composition determination by whole carcass proximate analysis. In the 100:0 diet, fish gained 3.8 g/d and the relative percentage gains for the series of diets with increasing MBM protein were 100, 83, 84, 68, and 39 % (39 % lower,$P < 0.05$). The relative percentage feed intakes were 100, 88, 87, 79, and 64 % (64 % lower, $P < 0.05$). The feed/gain ratios were .94, 1.01, .98, 1.19, and 1.53 (1.53 less efficient, $P < 0.05$), respectively. Dry matter and protein content of the whole body carcass decreased ($P < 0.05$), while ash and fat content increased ($P < 0.05$) with increasing increments of LAMBM protein, respectively. This works indicates that FM protein in semi-purified diets for rainbow trout can be replaced with 25 and 50 % LAMBM protein with only a 5 and 10 % loss in F/G, and up to 75 % with a 20 % loss in F/G.

Key words: Low ash meat and bone meal protein, Fish protein nutrition, Rainbow trout
(Not submitted to ASAS meetings)

Effects of replacing fish meal protein with low ash meat and bone meal protein as a major dietary ingredient on growth performance in rainbow trout (*Oncorhynchus mykiss*).

OBJECTIVES:

The objective was to evaluate the nutritional value of a low-ash meat and bone meal as a replacement for fish meal in the diets of cultured salmonid. This study also evaluated the effects of supplementing low-ash meat and bone meal with the amino acids methionine, lysine, and tryptophan.

EXPERIMENTAL PROCEDURES:

Four hundred and fifty rainbow trout (mean weight 35 g) were allotted to 6 treatments with three replicates per treatment. The 6 diets (% fish meal protein:% low ash meat and bone meal protein) were D100:0, D75:25, D50:50, D25:75, D0:100, and D0:100 + Supplementation with the amino acids methionine, lysine, and tryptophan. The low ash meat and bone meal replaced fish meal on an isonitrogenous and isocaloric basis with the protein to fat ration of the diets

remaining constant. A high quality fish meal (sardine meal, 70 % protein) served as the control protein source. Cellulose was used as a nutritionally inert ingredient to dilute the diet when necessary and fish and corn oils were used for energy adjustments. An amino acid digestibility study was added to the project and the results indicated a probable need for methionine, lysine, and tryptophan. The fish were hand-fed to satiety twice daily and were weighed on d 0, 21, 42, and 63. Feed intake, rate of gain, and feed efficiency were the criteria used to evaluate growth performance.

RESULTS:

The results from study H599 are presented in Tables 1-4. Table 1 shows the growth performance over the 9 week study. Table 1 shows that growth performance was poor for all fish throughout the 9 week study (approximately 2.2 g/day). The reason for this poor growth performance is not clear. Table 2 indicates that the fish grew the slowest during the first 3 weeks of the study (approximately 1.5 g/day). Although the fish grew poorly throughout the study, the results do suggest that fish meal protein can be replaced with 25, 50, and up to 75 % meat and bone meal protein with no differences ($P > 0.05$) in gain, intake, or feed efficiency. The addition of the amino acids methionine, lysine, and tryptophan had no effect ($P > 0.05$) on improving growth performance. Because growth rates were lower than expected, this study was repeated with some modifications.

Experiment H599
Low Ash Meat and Bone Meal Study with Rainbow Trout

Table 1. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout throughout the 9 week study.[ab]

	Diet Ratio[c]						
Item	D100:0	D75:25	D50:50	D25:75	D0:100	D0:100 + S	SEM
Gain/fish/day (g)	2.20[d]	2.34[d]	2.25[d]	2.10[d]	1.79[e]	1.76[e]	0.07
Feed intake/fish/day (g)	2.20[d]	2.21[d]	2.20[d]	2.19[d]	2.11[d]	2.06[d]	0.08
Feed/gain	1.00[d]	.95[d]	.98[d]	1.04[d]	1.18[e]	1.17[e]	0.02

[a]Data reported on final day of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM; 100 FM + Supplemented with tryptophan, methionine, and lysine.
[de]Means within the same row with different superscripts differ ($P < .05$).

Table 2. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during the first 3 weeks.[ab]

	Diet Ratio[c]						
Item	D100:0	D75:25	D50:50	D25:75	D0:100	D0:100 + S	SEM
Gain/fish/day (g)	1.49	1.73	1.63	1.49	1.41	1.36	0.09
Feed intake/fish/day (g)	1.37	1.51	1.50	1.40	1.44	1.38	0.09
Feed/gain	.94	.87	.92	.94	1.02	1.03	0.03

[a]Data reported on week 3 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM; 100 FM + Supplemented with tryptophan, methionine, and lysine

Table 3. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during weeks 3-6.[ab]

	Diet Ratio[c]						
Item	D100:0	D75:25	D50:50	D25:75	D0:100	D0:100 + S	SEM
Gain/fish/day (g)	2.22[de]	2.33[d]	2.18[de]	2.07[de]	1.81[def]	1.67[ef]	0.09
Feed intake/fish/day (g)	2.03[d]	2.11[d]	2.14[d]	2.06[d]	1.99[d]	1.97[d]	0.10
Feed/gain	.92[d]	.91[d]	.99[d]	1.00[d]	1.12[e]	1.73[e]	0.02

[a]Data reported on week 6 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM; 100 FM + Supplemented with tryptophan, methionine, and lysine.
[def]Means within the same row with different superscripts differ (P < .05).

Table 4. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during weeks 6-9.[ab]

	Diet Ratio[c]						
Item	D100:0	D75:25	D50:50	D25:75	D0:100	D0:100 + S	SEM
Gain/fish/day (g)	2.49[d]	2.48[d]	2.49[d]	2.32[d]	1.81[e]	1.88[e]	0.04
Feed intake/fish/day (g)	3.20[d]	3.01[d]	2.95[d]	3.10[d]	2.88[d]	2.83[d]	0.08
Feed/gain	1.09[d]	1.02[de]	1.00[de]	1.12[def]	1.34[df]	1.26[df]	0.02

[a]Data reported on week 9 of growth performance trial.
[b]Least square means pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM; 100 FM + Supplemented with tryptophan, methionine, and lysine.
[def]Means within the same row with different superscripts differ (P < .05).

Effects of replacing fish meal protein with low ash meat and bone meal protein or standard meat and bone meal as a major dietary ingredient on growth performance in rainbow trout (*Oncorhynchus mykiss*).

OBJECTIVES:
The objective was to evaluate the nutritional value of a low-ash meat and bone meal and a good quality standard meat and bone meal as a replacement for fish meal in the diets of cultured salmonids.

EXPERIMENTAL PROCEDURES:
Two hundred and twenty five rainbow trout (mean weight 120 g) were allotted to 9 treatments with three replicates per treatment. Within 9 diets, fish meal was replaced at increments of 25, 50, 75, or 100 % with low ash meat and bone meal or standard meat and bone meal (D100:0, D75:25, D50:50, D25:75, D0:100). The meat and bone meal replaced fish meal on an isonitrogenous and isocaloric basis with the protein to fat ration of the diets remaining constant. A high quality fish meal (sardine meal, 70 % protein) served as the control protein source. Cellulose was used as a nutritionally inert ingredient to dilute the diet when necessary and fish and corn oils were used for energy adjustments. The fish were hand-fed to satiety twice daily and were weighed on d 0, 21, 42, and 63. Feed intake, rate of gain, and feed efficiency were the

criteria used to evaluate growth performance. At the end of the study, a sub-sample of each replicate (n = 4) was sacrificed and body composition was analyzed using proximate analysis.

RESULTS:

The results are presented in Tables 1-11 as well as in the two attached abstracts. Table 1 shows the effect of different ratios of fish meal protein and standard meat and bone meal protein on body composition of eviscerated rainbow trout. The results indicate that there were no differences ($P > 0.05$) in dry matter and protein content of the whole body carcass in response to the dietary treatments. The results also indicate that there was an increase ($P < 0.05$) in carcass fat with the addition of standard meat and bone meal at 25 % and 100 % when compared to the control diet (D100:0). It is not clear why carcass fat did not increase when standard meat and bone meal was added at 50 and 75 %.

Table 2 shows the effect of different ratios of fish meal protein and standard meat and bone meal protein on growth performance over the 9 week study. Overall, the growth performance of these fish was better than in the previous study and consistent with industry standards. In the control diet (D100:0), fish gained 3.8 g per day and relative percentage gains for the diets with increasing standard meat and bone meal were 100, 90, 83, 85, and 59 % (59 % lower, $P < 0.05$). The feed/gain ratios were .94, .98, 1.04, 1.09, and 1.46 (1.46 less efficient, $P < 0.05$). There was no reduction ($P > 0.05$) in feed intake when compared to the control diet. These results suggest fish meal protein in semi-purified diets for rainbow trout can be replaced with 25 and 50 % standard meat and bone meal protein with only a 5 and 10 % loss in feed/gain, and up to 75 % with a 15 % loss in feed/gain.

Tables 3-5 show the effect of different ratios of fish meal protein and standard meat and bone meal protein on growth performance in 3 week increments. These results indicate that the fish grew well (approximately 3.0 to 4.0 g/day) throughout the study.

Table 6 shows the effect of different ratios of fish meal protein and low ash meat and bone meal protein on body composition of eviscerated rainbow trout. The results indicate that dry matter and protein content of the whole body carcass decreased ($P < 0.05$) while ash and fat content increased ($P < 0.05$) with increasing increments of low ash meat and bone meal. The deposition of more fat and less protein may affect the overall carcass dress out percentage on whole fish. Decreasing the carcass dress out percentage would be a major concern to the aquaculture industry and this concern must be addressed in future studies examining the replacement of fish meal with low ash meat and bone meal.

Table 7 shows the effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance over the 9 week study. In the control diet (D100:0), fish gained 3.8 g per day and relative percentage gains for the series of diets with increasing low ash meat and bone meal were 100, 83, 84, 68, and 39 % (39 % lower, $P < 0.05$). The feed/gain ratios were 0.94, 1.01, 0.98, 1.19, and 1.53 (1.53 less efficient, $P < 0.05$). The relative percentage feed intakes were 100 88, 87, 79, and 64 % (64 % lower, $P < 0.05$). These results suggest fish meal protein in semi-purified diets for rainbow trout can be replaced with 25 and 50 % low ash meat and bone meal protein with only a 5 and 10 % loss in feed/gain, and up to 75 % with a 20 % loss in feed/gain.

Tables 8-10 show the effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance in 3 week increments.

Table 11 shows the relative percentage of gain and feed intake in rainbow trout when fed standard fish meal protein versus standard meat and bone meal protein or low ash meat and bone meal protein.

Experiment 0498
Standard Meat and Bone Meal Study with Rainbow Trout

Table 1. The effect of different ratios of fish meal protein and standard meat and bone meal protein on body composition of eviscerated rainbow trout.[ab]

	Diet Ratio[c]					
Item, %	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Dry Matter	30.42[e]	30.42[e]	29.33[e]	29.26[e]	29.53[e]	0.50
Ash[d]	5.33[e]	6.62[e]	7.96[f]	7.92[f]	7.43[f]	0.51
Protein	73.05[e]	76.33[e]	72.48[e]	72.45[e]	71.98[e]	1.78
Fat[d]	27.21[e]	34.41[fg]	28.44[e]	30.52[eg]	36.61[fg]	1.94

[a]Data reported on final day of growth performance trial. Eviscerated carcasses included head and gills.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM.
[d]Percentages are presented on a dry matter basis.
[efg]Means within the same row with different superscripts differ (P < .05).

Table 2. The effect of different ratios of fish meal protein and standard meat and bone meal protein on growth performance of rainbow trout.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	3.78[d]	3.41[d]	3.13[d]	3.22[d]	2.24[e]	0.21
Feed intake/fish/day (g)	3.56[d]	3.33[d]	3.24[d]	3.50[d]	3.25[d]	0.16
Feed/gain	.94[d]	.98[d]	1.04[d]	1.09[d]	1.46[e]	0.05

[a]Data reported on final day of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM.
[de]Means within the same row with different superscripts differ (P < .05).

Table 3. The effect of different ratios of fish meal protein and standard meat and bone meal protein on growth performance of rainbow trout during the first 3 weeks.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	2.80[d]	2.25[d]	2.06[d]	2.62[d]	1.82[d]	0.22
Feed intake/fish/day (g)	2.33[d]	1.97[d]	1.90[d]	2.18[d]	2.03[d]	0.10
Feed/gain	.83[d]	.88[def]	.92[def]	.85[de]	1.12[ef]	0.04

[a]Data reported on week 3 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM.
[def]Means within the same row with different superscripts differ (P < .05).

Table 4. The effect of different ratios of fish meal protein and standard meat and bone meal protein on growth performance of rainbow trout during weeks 3-6.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	4.00[d]	3.88[d]	3.20[de]	3.37[de]	2.14[e]	0.22
Feed intake/fish/day (g)	3.80[d]	3.70[d]	3.57[d]	3.96[d]	3.59[d]	0.27
Feed/gain	.95[d]	.95[d]	1.01[de]	1.18[de]	1.69[e]	0.12

[a]Data reported on week 6 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM.
[de]Means within the same row with different superscripts differ (P < .05).

Table 5. The effect of different ratios of fish meal protein and standard meat and bone meal protein on growth performance of rainbow trout during weeks 6-9.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	4.52[d]	4.10[d]	3.78[d]	3.67[d]	2.76[d]	0.31
Feed intake/fish/day (g)	4.56[d]	4.33[d]	4.26[d]	4.34[d]	4.14[d]	0.21
Feed/gain	1.01[d]	1.06[d]	1.13[d]	1.18[de]	1.51[e]	0.05

[a]Data reported on week 9 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 FM:25 MBM; 50 FM:50 MBM; 25 FM:75 MBM; 0 FM:100 MBM.
[de]Means within the same row with different superscripts differ (P < .05).

Table 6. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on body composition of eviscerated rainbow trout.[ab]

	Diet Ratio[c]					
Item, %	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Dry Matter	30.42[e]	30.27[e]	29.84[e]	29.02[e]	27.65[e]	0.52
Ash[d]	5.33[e]	7.30[f]	7.18[f]	7.97[g]	9.65[h]	0.26
Protein	73.05[e]	62.57[f]	64.43[fg]	66.28[gh]	69.43[h]	1.07
Fat[d]	27.21[e]	34.95[f]	33.11[fg]	28.60[e]	30.24[eg]	1.24

[a]Data reported on final day of growth performance trial. Eviscerated carcasses included head and gills.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 LAMBM (Control); 75 FM:25 LAMBM; 50 FM:50 LAMBM;
25 FM:75 LAMBM; 0 FM:100 LAMBM.
[d]Percentages are presented on a dry matter basis.
[efgh]Means within the same row with different superscripts differ (P < .05).

Table 7. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	3.78[d]	3.16[e]	3.17[e]	2.57[f]	1.49[g]	0.02
Feed intake/fish/day (g)	3.56[d]	3.13[e]	3.11[e]	3.05[e]	2.28[f]	0.07
Feed/gain	.94[d]	1.01[de]	1.19[de]	1.19[e]	1.53[f]	0.04

[a]Data reported on final day of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 LAMBM (Control); 75 FM:25 LAMBM; 50 FM:50 LAMBM;
25 FM:75 LAMBM; 0 FM:100 LAMBM.
[defg]Means within the same row with different superscripts differ (P < .05).

Table 8. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during the first 3 weeks.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	2.80[d]	1.89[d]	2.13[d]	1.84[d]	1.34[e]	0.21
Feed intake/fish/day (g)	2.33[d]	1.90[e]	1.85[ef]	1.85[ef]	1.58[f]	0.05
Feed/gain	.83[d]	1.11[d]	.87[d]	1.01[d]	1.18[d]	0.12

[a]Data reported on week 3 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 LAMBM (Control); 75 FM:25 LAMBM; 50 FM:50 LAMBM; 25 FM:75 LAMBM; 0 FM:100 LAMBM.
[def]Means within the same row with different superscripts differ (P < .05).

Table 9. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during weeks 3-6.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	4.00[d]	3.70[de]	3.42[e]	2.72[f]	1.32[g]	0.08
Feed intake/fish/day (g)	3.80[d]	3.23[de]	3.24[de]	3.02[ef]	2.33[f]	0.12
Feed/gain	.95[d]	.94[d]	.95[d]	1.11[d]	1.77[e]	0.04

[a]Data reported on week 6 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 LAMBM (Control); 75 FM:25 LAMBM; 50 FM:50 LAMBM; 25 FM:75 LAMBM; 0 FM:100 LAMBM.
[defg]Means within the same row with different superscripts differ (P < .05).

Table 10. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout on weeks 6-9.[ab]

	Diet Ratio[c]					
Item	D100:0	D75:25	D50:50	D25:75	D0:100	SEM
Gain/fish/day (g)	4.52[d]	4.14[d]	3.97[d]	3.16[e]	1.18[f]	0.11
Feed intake/fish/day (g)	4.56[d]	4.25[d]	4.23[d]	4.30[d]	2.94[e]	0.19
Feed/gain	1.01[d]	1.05[d]	1.07[d]	1.37[de]	1.66[e]	0.08

[a]Data reported on week 9 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 LAMBM (Control); 75 FM:25 LAMBM; 50 FM:50 LAMBM; 25 FM:75 LAMBM; 0 FM:100 LAMBM.
[defg]Means within the same row with different superscripts differ (P < .05).

Table 11. Relative percentage gain and feed intake in rainbow trout when fed standard fish meal protein versus standard meat and bone meal protein or low ash meat and bone meal protein.

	Standard MBM			Low Ash MBM	
Diet	Gain	Feed	Diet	Gain	Feed
D100:0	100 %	100 %	D100:0	100 %	100 %
D75:25	90.33 %	93.64 %	D75:25	82.78 %	87.79 %
D50:50	82.80 %	89.15 %	D50:50	84.00 %	87.34 %
D25:75	85.28 %	98.19 %	D25:75	68.23 %	79.26 %
D0:100	59.35 %	91.38 %	D0:100	39.46 %	64.10 %

Effects of amino acid supplementation and bovine somatotropin administration in D100:0 and D25:75 from Experiment 0498 on growth performance in rainbow trout (*Oncorhynchus mykiss*).

OBJECTIVES:
The objectives were to determine the nutritional value of supplemental amino acids used in conjunction with low ash meat and bone meal as a replacement for fish meal and to determine the extent to which bST improves the efficiency of protein utilization from low ash meat and bone meal.

EXPERIMENTAL PROCEDURES:
Four hundred and eighty rainbow trout (mean weight 50 g) were allotted to 8 treatments with three replicates per treatment. The 8 diets (% fish meal protein:% low ash meat and bone meal protein) were D100:0, D25:75, D25:75 + Tryptophan (T), D25:75 + Methionine (M), D25:75 + Lysine (L), bST (120 μg/g BW/3 wks, Posilac©) + TML (75 MBM:25 FM + T + M + L), bST (120 μg/g BW/3 wks, Posilac©) + D100:0, and bST (120 μg/g BW/3 wks, Posilac©) + D25:75. The low ash meat and bone meal replaced fish meal on an isonitrogenous and isocaloric basis with the protein to fat ration of the diets remaining constant. A high quality fish meal (sardine meal, 70 % protein) served as the control protein source. Cellulose was used as a nutritionally inert ingredient to dilute the diet when necessary and fish and corn oils were used for energy adjustments. The fish were hand-fed to satiety twice daily and were weighed on d 0, 21, 42, and 63. Feed intake, rate of gain, and feed efficiency were the criteria used to evaluate growth performance. Body composition was not analyzed in this study.

RESULTS:
The results are presented in Tables 1-4. Table 1 shows the effects of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance over the 9 week study. Surprisingly, fish that received the control diet (D100:0) demonstrated decreased ($P < 0.05$) feed intake when compared to the other diets. The results from Table 1 also indicate fish meal protein can be replaced with 75 % low ash meat and bone meal with or without the supplementation of T, M, or L with no differences ($P > 0.05$) in weight gain when compared to the control diet. The feed/gain ratios were 0.97, 1.11, 1.14, 1.19, 1.14 for the D100:0, D25:75, D25:75 + T, D25:75 + M, and D25:75 + L diets, respectively. The feed efficiency results suggest that when fish meal protein is replaced with 75 % low ash meat and bone meal, with or without the addition of T, M, or L, feed efficiency is reduced ($P < 0.05$) when compared to the control diet (D100:0).

Also indicated in Table 1 are the growth performance results of the fish that received the bST + TML, bST + D100:0, and bST + D25:75 diets. The administration of bST in the bST + D100:0 diet increased gains 70 % and improved feed efficiency approximately 15 % when compared to the D100:0 diet. The improvement in weight gain is comparable to the responses that we have seen in previous studies using bST in rainbow trout but the improvement in feed efficiency is lower than previous studies. Using bST + D100 as the control diet and comparing it to the bST + D25:75 diet (no supplementation of T, M, or L), fish gain is decreased ($P < 0.05$) by approximately 20 %. When fish meal protein was replaced with 75 % low ash meat and bone meal, with or without the addition of T, M, or L, feed efficiency is reduced ($P < 0.05$) 5 and 10 %

for the bST + TML and bST + D25:75 diets, respectively. It appears that bST has little to no effect on improving the efficiency of protein utilization with low ash meat and bone meal.

Tables 2-4 show the effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance in 3 week increments.

The last objective of this project was to determine the availability of phosphorus in meat and bone meal and to assess phosphorus in the aquacultural effluent. Due to the fact that Dr. Gerald Schelling recently passed away, this part of the project was not completed. However, the availability of phosphorus in meat and bone meal is of great concern due to the potential eutrophication of the aquatic ecosystem. This problem must be addressed in future studies examining the replacement of fish meal with meat and bone meal.

Table 1. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout throughout the 9 week study.[ab]

Item	Diet Ratio[c]								SEM
	D100:0	D25+75	D25+75 T	D25:75 M	D25:75 L	bST +TML	bST + D100:0	bST + D25:75	
Gain/fish/day (g)	1.95^{d}	1.94^{d}	1.97^{d}	1.88^{d}	2.04^{de}	2.71^{i}	2.79^{i}	2.26^{g}	.02
Feed intake/fish/day (g)	1.88^{d}	2.17^{e}	2.24^{f}	2.23^{f}	2.31^{g}	2.43^{h}	2.33^{g}	2.14^{e}	.01
Feed/gain	.97^{d}	1.11^{e}	1.14^{f}	1.19^{g}	1.14^{f}	.90^{h}	.84^{i}	.95^{j}	.002

[a]Data reported on final day of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 MBM:25 FM; 75 MBM:25 MBM + Tyrptophan; 25 MBM:75 FM + Methionine; 25 MBM:75 FM + Lysine; bST (120 µg/g BW/3 wks) + 75 MBM:25 FM + T + M + L; bST (120 µg/g BW/3 wks) + 100 FM:0 MBM; bST (120 µg/g BW/3 wks) + 25 MBM:75 FM.
[defghij]Means within the same row with different superscripts differ (P < .05).

Table 2. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during the first 3 weeks.[ab]

Item	Diet Ratio[c]								SEM
	D100:0	D25+75	D25+75 T	D25:75 M	D25:75 L	bST +TML	bST + D100:0	bST + D25:75	
Gain/fish/day (g)	1.05^{d}	1.38^{e}	.92^{df}	1.00^{df}	1.08^{dfg}	1.65^{h}	1.95^{i}	1.22^{dei}	.03
Feed intake/fish/day (g)	1.05^{d}	1.38^{d}	1.12^{d}	1.11^{d}	1.26^{d}	1.24^{d}	1.52^{d}	1.12^{d}	.10
Feed/gain	.99^{d}	1.00^{d}	1.22^{de}	1.14^{de}	1.18^{de}	.86^{df}	.78^{df}	.92^{df}	.04

[a]Data reported on week 3 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 MBM:25 FM; 75 MBM:25 MBM + Tyrptophan; 25 MBM:75 FM + Methionine; 25 MBM:75 FM + Lysine; bST (120 µg/g BW/3 wks) + 75 MBM:25 FM + T + M + L; bST (120 µg/g BW/3 wks) + 100 FM:0 MBM; bST (120 µg/g BW/3 wks) + 25 MBM:75 FM.
[defghi]Means within the same row with different superscripts differ (P < .05).

Table 3. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during weeks 3-6.[ab]

Item	Diet Ratio[c]								SEM
	D100:0	D25+75	D25+75 T	D25:75 M	D25:75 L	bST +TML	bST + D100:0	bST + D25:75	
Gain/fish/day (g)	2.14^{d}	1.83^{def}	1.74^{de}	1.75^{de}	1.93^{def}	2.19^{def}	2.43^{df}	1.84^{de}	.11
Feed intake/fish/day (g)	2.27^{d}	2.35^{d}	2.22^{d}	2.53^{d}	2.64^{d}	2.73^{d}	2.76^{d}	2.49^{d}	.13
Feed/gain	1.06^{d}	1.29^{def}	1.28^{def}	1.45^{ef}	1.36^{ef}	1.25^{def}	1.14^{de}	1.36^{ef}	.04

[a]Data reported on week 6 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 MBM:25 FM; 75 MBM:25 MBM + Tyrptophan; 25 MBM:75 FM + Methionine; 25 MBM:75 FM + Lysine; bST (120 µg/g BW/3 wks) + 75 MBM:25 FM + T + M + L; bST (120 µg/g BW/3 wks) + 100 FM:0 MBM; bST (120 µg/g BW/3 wks) + 25 MBM:75 FM.
[def]Means within the same row with different superscripts differ (P < .05).

Table 4. The effect of different ratios of fish meal protein and low ash meat and bone meal protein on growth performance of rainbow trout during weeks 6-9.[ab]

Item	Diet Ratio[c]								SEM
	D100:0	D25+75	D25+75 T	D25:75 M	D25:75 L	bST +TML	bST + D100:0	bST + D25:75	
Gain/fish/day (g)	2.63^{d}	2.63^{de}	3.25^{def}	2.90^{de}	3.09^{de}	4.25^{g}	3.97^{fg}	3.73^{efg}	.13
Feed intake/fish/day (g)	2.33^{d}	2.77^{d}	3.38^{e}	3.11^{e}	3.06^{e}	3.15^{e}	2.71^{de}	2.81^{de}	.11
Feed/gain	.88^{d}	1.06^{e}	1.04^{e}	1.07^{e}	.99^{e}	.74^{f}	.68^{f}	.76^{f}	.02

[a]Data reported on week 9 of growth performance trial.
[b]Least square means and pooled standard error of the mean (SEM).
[c]Diets = 100 FM:0 MBM (Control); 75 MBM:25 FM; 75 MBM:25 MBM + Tyrptophan; 25 MBM:75 FM + Methionine; 25 MBM:75 FM + Lysine; bST (120 µg/g BW/3 wks) + 75 MBM:25 FM + T + M + L; bST (120 µg/g BW/3 wks) + 100 FM:0 MBM; bST (120 µg/g BW/3 wks) + 25 MBM:75 FM.
[defgh]Means within the same row with different superscripts differ (P < .05).