Department of Agriculture, Trade and Consumer Protection
Division of Marketing
Agricultural Development & Diversification Program (ADD)

1999-00 Grant Project Final Report

Contract Number: 14002

Grant Project Title: Enhancing Performance of Farm-Raised Brook Trout (*Salvelinus fontinalis*) with Natural and Artificial Diets (Year 2)

Project Beginning Date: September 1, 1999 Project Ending Date: September 1, 2000

Amount of Funding Awarded: $23,320

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Enhancing Performance of Farm-Raised Brook Trout (*Salvelinus fontinalis*) with Natural and Artificial Diets (Year 2)

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Summary

1) Intent of Project

Determine the impact of a natural diet of baitfish on the nitrogenous waste production of brook trout raised under five thermal regimes. Compare the nitrogenous waste production of brook trout raised on a natural diet with the waste production of trout raised on an artificial pellet food diet. Determine if alternative diets can be used to improve the culturing protocol of brook trout, while enhancing the growth and marketability of trout to fee-based operations and private stocking clubs, while lowering the costs and environmental impact that such facilities must endure.

A) How was it projected to benefit Wisconsin Agriculture?

This study examined the scientific feasibility to the aquaculture industry of enhancing brook trout performance and marketability by the addition of natural food type (baitfish) during trout production. Both brook trout and baitfish aquaculture operations may experience increased demand in production and trout facilities would be able to offer greater choices to customers, with standard artificially fed trout and enhanced, naturally fed trout, that may provide increased angler challenge and improved behavior.

Overall, recommendations regarding the best commercial rearing techniques, as influenced by food type, will be made for optimal temperature requirements and growth rates. Additionally, recommendations as to the impact that natural and artificial feeds have on the surrounding freshwater systems will be made, with reference to possibly decreasing nitrogenous nutrient input from naturally and artificially fed trout.

B) Was it necessary to adjust the objectives during the project?

All of the proposed objectives were met during the completion of the project.

2) Describe the work conducted in this project.

Protocol

Farm-raised brook trout were acquired from Silver Moon Springs Trout Farm (Elton, WI) and baitfish (fathead minnows) were obtained from Gollon Brothers Wholesale Live Bait (Stevens Point, WI). Brook trout were reared in

indoor, flow-through 300-gallon tanks at 9°C. An experimental tank system was constructed so that individual trout could be fed and nitrogenous waste output could be monitored. Experiments were conducted to evaluate the 24-hour nitrogenous waste production by testing temperatures (7, 9, 11, 15, 19°C) and food types (natural/artificial).

Artificial rations (pelleted Purina Trout Chow) were supplied at maximum consumption rates (defined as the maximum amount of feed the trout would consume in one hour). Natural rations (baitfish) were supplied based on the maximum amount observed to be consumed during 30 minute feeding periods. One hour after feeding, individual trout were transferred to 2.5 L aquaria and water samples were collected every hour for 12 hours and then every other hour for the remaining 12 hours. Dissolved oxygen, pH, alkalinity and hardness were monitored during the 24-hours. Light conditions were kept constant (24 light : 0 dark). At the conclusion of each experiment wet weight and total length of each trout were recorded.

Each water sample was tested for ammonia (NH_4-N), nitrate (NO_3-N), nitrite (NO_2-N), total nitrogen (TN), and urea.

Comparisons were made between nitrogenous waste production of brook trout raised on natural and artificial diets and waste production as a function of temperature regimes. These evaluations were used to help determine the optimal rearing conditions and food types for least effluent production in farm-raised trout.

A) How did the grant funds assist you in the project?

Grant funds were used to purchase the ammonia, nitrate, nitrite, total nitrogen, and urea test kits that were ISO 9000 certified. Certification was necessary so that results could be compared to allowable nitrogen levels as outlined by the USEPA.

B) What successes did you achieve with this grant project?

Two notable successes were achieved with this project:

- Optimum growth of brook trout was achieved at colder water temperatures (7 and 9°C) when the trout were fed a natural diet of baitfish. Conversely, better trout growth was achieved at warmer water temperatures (15 and 19°C) when the trout were fed an artificial pellet diet.

- A natural baitfish diet showed lower nitrite production at 9°C, lower nitrate production at 11°C, and lower urea production at 15°C. An artificial diet showed lower urea, ammonia, and total-N at 7°C, lower total-N at 9°C, lower ammonia production at 11°C, and lower nitrate and ammonia production at 15°C.

C) What challenges did you face with your grant project?

All of the objectives of this grant were completed with few challenges. Slight difficulty occurred in getting the brook trout to feed at 19^{o}C, but repeated attempts ultimately proved successful.

3) Describe the public outreach efforts of this project.

A) What literature or educational materials were produced through this project?

A project summer will be distributed at the next WI Aquaculture Industry Advisory Council meeting (12/2000).

B) What presentations, field days or other events were given related to this project?

Presentations:

- Dr. Chris Hartleb will be presenting the results of this project at the 2001 American Fisheries Society Annual Meeting (8/2001).
- Josh Eastman, a student at UW-Stevens Point, presented initial results of this project at the 1st Annual UWSP Research Symposium (4/2000).
- Josh Eastman and Dr. Chris Hartleb will be presenting the results of this project at the Mid-West Fish & Wildlife Conference (12/2000).

Field Days:

- Mike Bandli, WiDATCP, ADD-Grant Program, 9/2000.
- Women in Science, UW-System, 11/2000.

4) Describe the results of this project.

A) Did the grant project results meet your original expectations? Why or why not?

Original expectations were that brook trout would grow significantly faster at all temperatures when fed a natural diet of baitfish. Results indicated that brook trout did grow faster at colder temperatures (7 and 9^{o}C) when fed baitfish, but grew better at warmer temperatures (15 and 19^{o}C) when fed an artificial pellet diet. Initial expectations included a mixed pattern of waste production where some nitrogenous compounds were expected to be greater with a natural diet, while others should increase with an artificial diet. Results showed that an artificial diet of processed ingredients generally produced lower levels of nitrogenous waste products, with slight exceptions at 9, 11, and 15^{o}C for nitrite, nitrate, and urea, respectively.

B) What new agricultural products, technologies or production methods were developed through this project?

Scientific results from this project can be applied to brook trout production methods with the desired goal of increasing cultured brook trout production while minimizing nitrogenous waste production. Overall, recommendations include:

- Feeding brook trout natural diet items, specifically baitfish, during colder months (water temperature < 11^{o}C) to maximize growth and production.
- Feeding brook trout artificial, pellet food during warmer months (water temperature > 11^{o}C) to maximize growth and production.
- Where trout farm effluent is returned to a natural surface water system, artificial pellet food contributes lower concentrations of nitrogenous waste than a natural, baitfish diet.
- A baitfish diet can still be offered to cultured brook trout during colder months (water temperature < 11^{o}C), even though greater concentrations of most nitrogenous waste products will be produced, since primary production in surface water systems is usually limited during colder periods.

5) How will the Wisconsin agriculture industry be able to use the information from this project?

Results presented in this report can be applied at aquaculture facilities to enhance the growth of brook trout, while lowering the effluent impact on discharge surface water.

6) Include any research data that support your conclusions for this project.

Growth of brook trout raised on natural and artificial diets (Figure 1):

- Percent average growth of brook trout was greater at or below 11^{o}C when trout were fed a natural, batfish diet.
- Percent average growth of brook trout was greater above 12^{o}C when trout were fed an artificial pellet diet.

Nitrogenous waste production by brook trout raised on natural and artificial diets (Table 1):

- Brook trout produced less nitrite (NO_2-N) at 9^{o}C when fed a natural, baitfish diet. Nitrate (NO_3-N) production was less at 11^{o}C and urea production was less at 15^{o}C, when brook trout were fed a natural diet.
- When compared to a natural diet, brook trout produced less ammonia (NH_4-N) waste at 7, 11, and 15^{o}C when fed an artificial, pellet diet. Less total nitrogen (TN) was produced by brook trout fed an artificial diet at 7 and 9^{o}C, than a natural diet. Less urea and nitrate (NO_3-N) were produced by brook trout fed artificial diets at 7 and 15^{o}C, respectively.

Significantly greater ($p<0.05$, ANOVA, $F=9.24$, $df=4$) average growth was observed for brook trout raised at warmer temperatures (15 and 19^{o}C) than at colder temperatures (7 and 9^{o}C) when fed an artificial diet. Brook trout raised at 11^{o}C and fed a natural diet of baitfish displayed significantly greater ($p=0.01$, ANOVA, $f=23.28$, $df=4$) growth than at any other temperature. Growth by brook trout fed a natural diet was significantly less ($p<0.05$, ANOVA, $F=23.28$, $df=4$) at

warmer temperatures (15 and 19^{o}C) than at colder (<12^{o}C). Brook trout showed a slight increase in growth at the coldest temperature (7^{o}C).

Overall, brook trout raised at 7^{o}C grew significantly better ($p<0.01$, t-test, $t=5.17$, $df=4$) when raised on a natural diet of baitfish. Trout raised at 9^{o}C did not show any significant difference ($p>0.05$) in growth when fed either natural or artificial diets. Trout fed a natural diet grew significantly greater ($p<0.01$, t-test, $t=6.99$, $df=14$) at 11^{o}C when compared to trout fed an artificial pellet diet. No significant difference ($p>0.05$) in growth was observed at 15^{o}C for trout raised on natural or artificial diets. Trout fed an artificial pellet diet grew significantly greater ($p<0.01$, t-test, $t=4.02$, $df=14$) at the warmest temperature of 19^{o}C, when compared to trout fed a natural diet at the same temperature.

Significantly greater ($p=0.04$, Kruskal-Wallis test) amounts of nitrite (NO_2-N) were produced by brook trout fed an artificial diet at 9^{o}C, when compared to trout fed a natural diet. Urea production was significantly ($p=0.002$, K-W test) lower at 7^{o}C when trout were fed an artificial diet, but increased significantly ($p=0.015$, K-W test) at 15^{o}C, where a natural diet resulted in less urea waste being produced by brook trout. Nitrate (NO_3-N) production showed mixed results at warmer temperatures with significantly more ($p=0.045$, K-W test) nitrate produced by brook trout at 11^{o}C when fed an artificial diet, but significantly less ($p=0.026$, K-W test) nitrate produced by brook trout at 15^{o}C on the same artificial diet.

Ammonia (NH_4-N) production, which constitutes the majority of nitrogenous waste produced by freshwater fish, was significantly less ($p=0.015$ (7^{o}C); $p=0.04$ (11^{o}C); $p=0.009$ (15^{o}C), K-W test) at 7, 11, and 15^{o}C when brook trout were fed an artificial diet.

Total nitrogen (TN) production, which is composed of nitrite, nitrate, ammonia, urea, particulate-N, and organic-N, was significantly less ($p=0.002$ (7^{o}C); $p=0.004$ (9^{o}C), K-W test) for brook trout fed an artificial diet at 7 and 9^{o}C. Trout fed baitfish, that were composed of indigestible calcified parts, produced greater amounts of organic-N and particulate-N. This skeletal material may have contributed to the increase in total nitrogen production at colder temperatures.

Conclusions

This study examined the scientific feasibility of raising brook trout on a natural diet of baitfish instead of the standard pellet trout food. The goal was to better understand the growth patterns and nitrogenous waste production that modified diets exerted on the performance of trout raised under a five-tier thermal regime.

Overall, results from this study showed that brook trout fed a natural diet of baitfish did display enhanced growth at colder temperatures, with a two-fold increase in growth at 11^{o}C, when compared to brook trout fed an artificial diet. Brook trout fed a natural diet at 7, 9 and 11^{o}C either matched or exceeded the growth shown by brook trout raised under the same thermal conditions, but fed an artificial diet of pellet trout food. Brook trout raised at warmer temperatures, of

15 and 19^{o}C, and fed a natural diet grew less than trout raised under identical conditions, which were fed an artificial diet.

Nitrogenous waste production results showed that, generally, an artificial diet produced less nitrite, urea, total-N, nitrate, and ammonia, when compared to waste produced by brook trout fed a natural diet. Exceptions included nitrite, nitrate, and urea at 9, 11, and 15^{o}C, respectively. These results indicate, that if nitrogenous waste production is the only factor being considered, a strict artificial diet would result in less nitrogen-based waste being produced by brook trout under all 5 thermal conditions.

If a synergistic model, of growth and nitrogenous waste production, is followed, the two-tier feeding strategy (previously discussed in Year 1 results) may still be adopted by the aquaculture industry to improve brook trout performance and improve culturing protocol. Even though a natural diet of baitfish increases the nitrogenous waste production by brook trout, the increased growth shown by trout at colder temperatures ($\leq$ 11^{o}C) will have a greater impact on trout production than the waste will have on the surrounding freshwater systems. Effluent leaving the culture facility during colder months may contain higher levels of nitrogen-based waste, but due to the coldwater temperatures, the impact that the waste will have on primary production will be minimal. The nitrogenous wastes examined in this study are carried as gases and liquids in freshwater. Therefore, they will not linger in streams and rivers and should be removed from the system when water temperatures increase.

Feeding brook trout a natural (baitfish) diet during colder seasonal periods has the additional benefit of increasing the production demand for the baitfish industry and improving the growth of brook trout during winter and spring periods. Eutrophication impact should be minimal during this period, even if slightly higher levels of nitrogenous waste are produced, due to the lack of primary production in freshwater systems during cold temperature months.

Table 1. Mean Total Production (mg/kg fish wet weight) Over a 24-hour Period

Temperature (°C)	Food type	NO2-N	Urea	Total-N	NO3-N	NH4-N
7	Natural	3.96±0.84	935.32±123.18	16154.42±1308.29	213.53±63.95	218.01±33.52
7	Artificial	3.56±1.10	182.40±61.11	1195.51±243.14	222.43±64.34	132.81±8.14
9	Natural	1.43±0.27	529.49±233.67	9788.13±874.58	29.39±11.20	173.50±11.47
9	Artificial	5.12±2.20	383.19±151.43	4438.23±698.29	59.04±44.60	167.57±26.18
11	Natural	0.88±0.56	612.57±224.38	9729.61±1238.22	41.27±13.34	284.51±25.74
11	Artificial	1.89±0.45	725.26±269.62	4852.80±1619.28	164.10±43.52	190.27±20.68
15	Natural	2.30±1.04	161.52±45.62	10580.04±1355.23	269.43±49.78	374.78±69.69
15	Artificial	1.68±0.48	542.31±131.84	6313.93±2385.98	92.28±27.89	159.67±11.80
19	Natural	4.44±0.77	913.80±183.94	9110.14±727.51	21.88±11.55	389.48±68.46
19	Artificial	6.99±2.74	6101.76±2648.01	7761.02±1521.55	2270.46±1877.92	218.81±34.63

Table 2. Conversion values for water temperature from Celsius to Fahrenheit.

Celsius	*Fahrenheit*
7	44.6
9	48.2
11	51.8
15	59.0
19	66.2

Figure 1

Growth of Brook Trout fed Natural (baitfish) and Artificial (pelleted) Diets Over a 30 Day Period at Five Temperatures