Growth Response of the Yellow Perch, *Perca flavescens* Mitchill, to Different Levels of Protein in Formulated Diets

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사료의 단백질 함량이 옐로우 · 퍼치의 성장에 미치는 영향

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ABSTRACT

The growth response of the yellow perch, a highly proteinaceous food feeder in nature, to different protein levels (50, 40 and 27%) in formulated diets was determined over a 20-week period. Approximately 23% of dietary protein could be spared by substituting less expensive carbohydrate and lipid materials without any noticeable ill-effects or reduction in weight gains. In turn, there was no statistically significant difference between total weight gains of fish fed at three different levels of protein diets, although fish on the 50 and 40% protein diets grew better in the first few weeks. A shift in the protein requirements occurred after about 10 weeks of rearing. Growth efficiencies(growth/food intake) became nearly the same at all levels of protein and decreased consistently throughout the remainder of the study period. The results indicate that young yellow perch(6g initial weight) can grow normally with the 27% protein diet after about 10 weeks of initial feeding with higher protein diets(or regular commercial diets).

要 約

인공사료의 단백질 함량이 옐로우 · 퍼치(Percidae)의 성장에 미치는 영향을 조사하였다. 단백질 함량 50, 40 및 27%의 정제된 사료를 20주간 투여한 결과 사육초기에는 50% 및 40% 단백질 사료 투여군이 27% 사료투여군 보다 성장이 빨랐으나 10주이후부터는 성장이나 사료전환효율이 거의 동일하였고 3개 실험군 간에 통계적으로 유의성이 있는 차이를 찾아 볼 수 없었다.

옐로우 · 퍼치의 치어(체중 약 6g)는 사육개시후 약 10주 이후 혹은 체중이 약 12g에 달했을 때부터는 단백질 요구량이 현저하게 감소하는 경향을 나타내어 27% 단백질 사료로서 정상적인 성장을 보여 주었다. 이는 자연계에서 매우 강한 육식성으로 고단백 식성 어류인 퍼치를

일반상업용 사료(50—56% 단백질)보다 약 23% 이상의 단백질이 절감된 27% 단백질 사료로 실내에서 사육할 수 있음을 의미한다.

INTRODUCTION

It is generally believed that fish have a higher requirement for protein than homoiothermic animals(Gerking 1955). Delong and his associates(1958) found that the protein requirements of chinook salmon(*Oncorhynchus tschawytscha*) were two to four times more than those of birds and mammals.

The protein requirements of fish vary with different species, water temperature, age and growth stage, size, and quality of protein and other nutrients. As protein intake is a major determinant for growth, an increased amount of protein intake should increase the growth of fish. Once it reaches a dietary protein level that produce the maximum growth, further increases in protein intake should not result in increased weight gain. Studies have shown that excessive protein in the diets may reduce the weight gain of fish(Dupree and Sneed 1966 ; Ashley 1972 ; Lee and Putnam 1973), and even be toxic to young salmon(Delong *et al.* 1958).

Efficiency of protein utilization or protein efficiency ratio(PER) declines if fish are fed beyond the optimum level(Tunison 1940 ; Dupree and Sneed 1966 ; Satia 1974 ; Siddiqui *et al.* 1988). Protein utilization also decreases with increasing size and age(Gerking 1952) and thus fish require lesser amounts of protein in their diet as they grow. It is important for the fish culturists to determine minimum protein levels for maximal growth as well as the size range of fish in which any change in the protein requirements may occur.

The protein content of a formulated fish diet may be lowered by using other supplemental energy sources, e.g. carbohydrate and lipids. Since protein is one of the most expensive dietary ingredients, it is desirable to examine the extent to which protein can be replaced with less costly nutritional materials. The "Protein sparing" by other nutrient sources has been studied for trouts-(Phillips *et al.* 1966, 1967 ; Lee and Putnam 1973 ; Zeitoun *et al.* 1973), salmon(Buhler and Halver 1961 ; Combs *et al.* 1962 ; Fowler *et al.* 1966 ; Zeitoun *et al.* 1974), catfish(Nail 1962 ; Tiemeirer 1965), and eels(Degani and Viola 1987).

In previous work(Calbert *et al.* 1974 ; Huh *et al.* 1976), the yellow perch were grown under controlled environmental conditions using a 56% protein diet. The purpose of this study was to determine if the yellow perch, a highly proteinaceous food feeder in nature, could grow normally with reduced protein diets, and if there was any change in protein requirement with increasing body weight or age.

MATERIALS AND METHODS

Composition and nutritional characteristics of three protein diets(50, 40, and 27%) are shown in Tables 1 and 2.

One hundred twenty yellow perch fingerlings, averaging 2.5g in weight, were acclimatized to 22℃(from 16℃ in holding tank) for ten days before starting the experiment. Twenty randomly selected fish were placed in each of six 110-liter slate bottom aquaria. Mean weight of fish in each aquarium was fairly uniform ranging from 2.45 to 2.55g. The six aquaria were divided into three

Table 1. Composition of three diets with 50, 40, and 27% protein levels. Three protein mixtures were made by the Vita-Plus Corporation, Madison, Wisconsin.

Ingredient	Protein level		
	50%	40%	27%
		(1b/ton)	
Peruvian fish meal	1,000	800	400
Delactosed whey powder	140	100	100
Soya flour	300	200	100
Brewers yeast	100	100	100
Soy oil	180	300	300
Blood flour	200	100	50
Vitamin premix[1]	80	80	80
Oat flour	–	320	870
	2,000	2,000	2,000

[1]Containing the following vitamins: Vitamins A, B_{12}, D_3, E & K ; riboflavin ; niacin ; d-pantothenic acid ; choline chloride ; pyridoxine ; folic acid ; thiamin ; biotin ; and ascorbic acid.

Table 2. Proximate analysis of the three diets with 50, 40 and 27% protein levels.

Composition	Protein level		
	50%	40%	27%
Protein (%)	50.29	39.95	26.85
Fat (%)	13.12	19.14	19.10
Fiber (%)	1.68	1.75	2.20
Calcium (%)	2.60	2.08	1.08
Phosphorous (%)	1.66	1.39	0.92
Vitamin A(USP units/1b)	2,949.00	2,947.00	2,947.00
Vitamin D_3(USP units/1b)	590.00	590.00	590.00
Vitamin E(I units/1b)	85.00	90.00	93.00
Riboflavin(mg/1b)	26.45	26.04	25.67
Niacin(mg/1b)	272.62	270.03	266.45
d-pantothenic acid(mg/1b)	29.51	29.47	29.73
Choline(mg/1b)	2,708.00	2,555.00	2,353.00
Vitamin B_{12}(mg/1b)	44.95	38.00	24.36
Pyridoxine(mg/1b)	19.65	19.65	19.65
Folic acid(mg/1b)	4.45	4.40	4.33
Thiamine(mg/1b)	22.21	24.54	28.59
Biotin(mg/1b)	385.00	385.00	390.00
Vitamin K(mg/1b)	6.29	6.29	6.29
Ascorbic acid(mg/1b)	196.50	196.50	196.50
Lysine (%)	3.52	2.71	1.61
Methionine (%)	1.35	1.08	0.65
Tryptophane (%)	0.61	0.48	0.34
Threonine (%)	1.87	1.49	1.02
Cystine (%)	0.80	0.63	0.42
ME(poultry figures, cal/K)	3,214.00	3,536.00	3,445.00

pairs. Each pair, consisting of duplicate aquaria containing 20 fish, was fed with 50, 40, and 27% protein diets, respectively. One aquarium from each pair was administered as a control and fed with the original diet throughout the study. As the fish in the remaining aquarium of each pair reached 6g, they were transferred to another aquarium and fed on a diet containing the next lower protein content. For example, as a fish being fed the 50% protein diet reached the 6g size, it was transferred to another aquarium and fed in the 40% protein diet. This same procedure was followed in reducing the dietary protein level (27%) when the fish reached the 12g size. Those starting on the 27% protein diet remained on this diet throughout the test period.

Fish were fed twice a day at the rate of 3% of wet body weight per day. Fish were weighed every week or every two weeks and the ration was adjusted to new weight on a bi-weekly basis. All fish were kept under the aquarium condition of 22℃ with 16-hour photoperiod for twenty weeks.

Data were statistically analyzed through analysis of variance and new Waller-Duncan's Bayesian test(Waller and Duncan 1969, 1970) to evaluate significances between the treatment means of growth.

RESULTS AND DISCUSSION

The weight gains were nearly the same in fish fed the 50 and 40% protein diets but slightly lower in the fish with the 27% protein(Fig. 1). Averages increases in weight from 2.5g fish were 9.3, 8.9 and 6.0g, respectively. The regression equations for growth, based on weight gain against time, reveal that the regression coefficient for the group fed the 40% protein was the highest among the means of control groups. The regression formulae computed are:

$\log Y = 0.390 + 0.505 \log X$(50%protein, $r^2 = 0.989$),

$\log Y = 0.355 + 0.530 \log X$(40%protein, $r^2 = 0.966$),

$\log Y = 0.351 + 0.431 \log X$(27%protein, $r^2 = 0.980$),

where Y is weight gain in grams and X is time in weeks. In all cases, the correlations were highly significant.

The growth efficiency or feed efficiency of the 50% protein diet was very high in the beginning then decreased consistently with time as they grew(Fig. 2). The efficiency at the 40% protein diet was slightly lower than the 50% protein diet but increased until fourth week from 77 to over 90%, then declined thereafter as the 50% diet. The growth efficiency at the 27% protein diet was very low with less than 60% until eighth week. But it slowly increased to a peak of 64% during the eighth week then declined. Apparently fish required more time to adjust to the lower levels of protein in the diets. After the tenth week, however, the regression lines for the growth efficiency of the three protein diets were nearly paralleled to each other until end of the study. Therefore, it can be assumed that the shift in protein requirements of the yellow perch fingerlings might have occurred around ten to eleventh week of the experiment.

Analysis of variance revealed no evidence of real difference among the mean weight gains of three groups. Mortalities during the entire experiment were about 5% for the 40% diet and 15% for the fish on both the 50 and 27% protein diets.

The comparison of weight gains in those transferred fish(>6g) against the control groups are summarized in Table 3. Growth of fish transferred from the 50% to 40% protein and from the 40% to 27% diets were generally lower than those on the same diets but without transferring

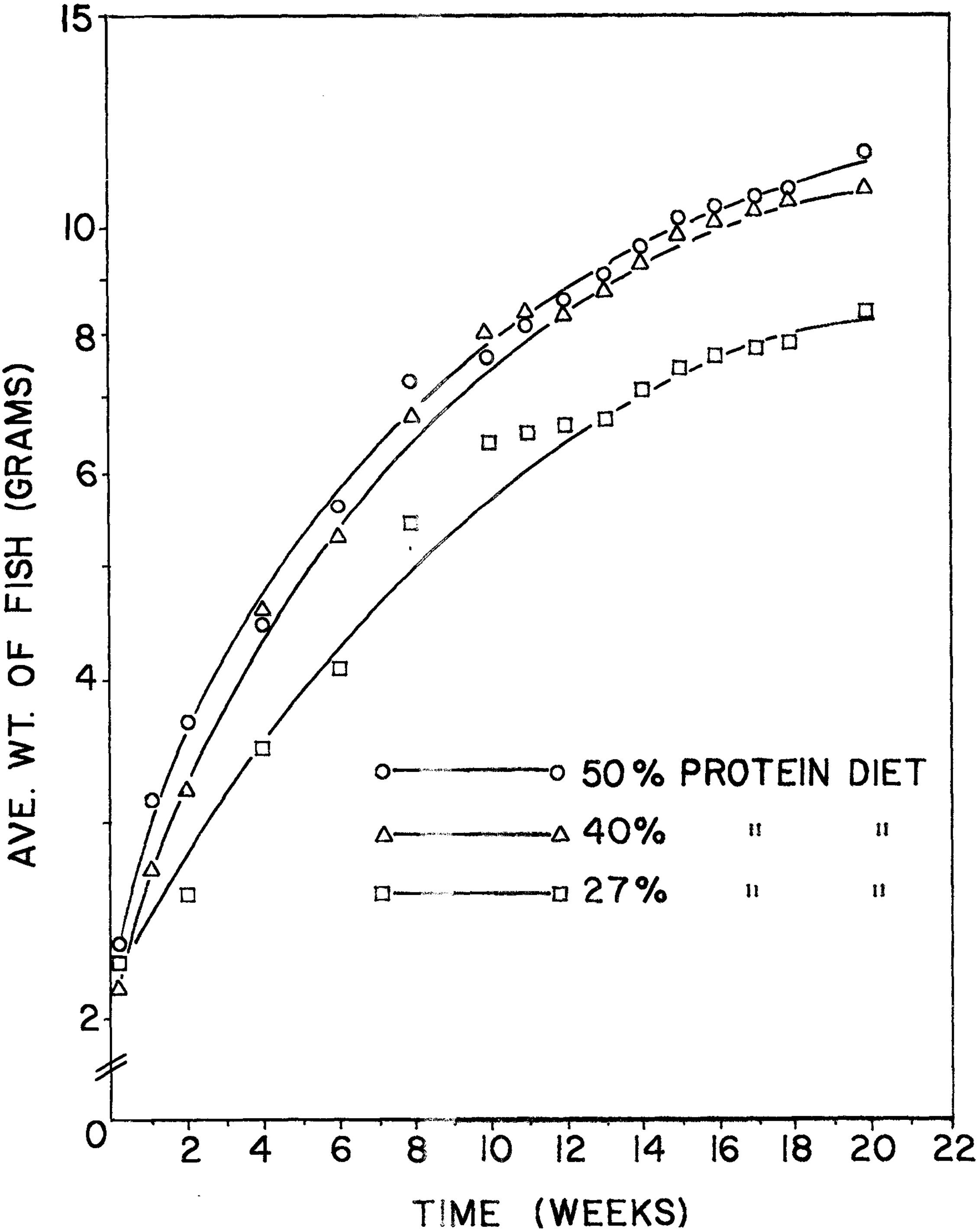

Fig. 1. Growth of the yellow perch fingerlings fed the 50, 40, and 27% protein diets for 20 weeks. Fish were held at 22℃ and 16hr photoperiod.

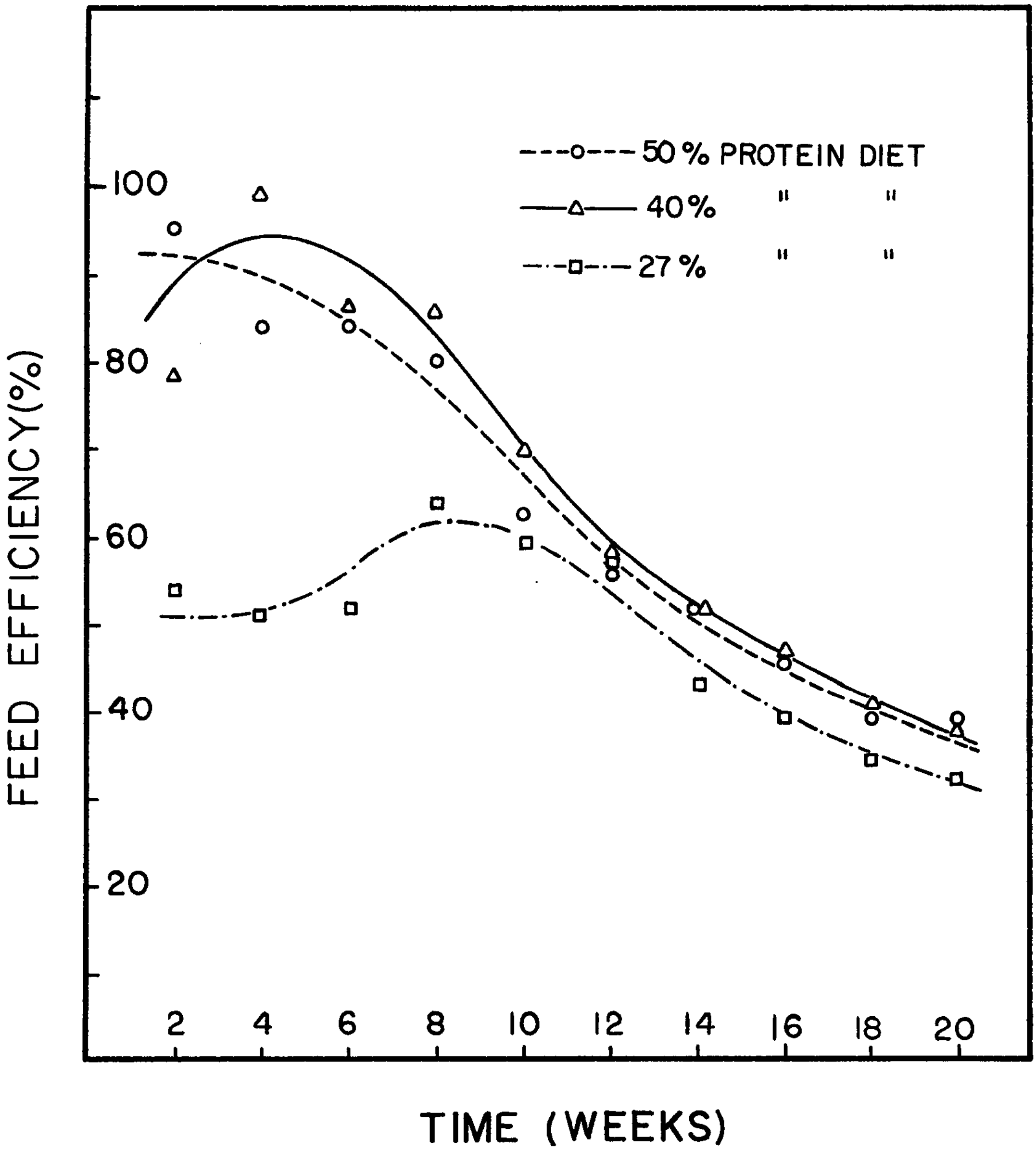

Fig. 2. Feed efficiency (or growth efficiency - %) of 50, 40 and 27% protein diets fed to yellow-perch for 20 weeks.

throughout the study period. However, this trend appeared to be only true for the fish smaller than 12g in weight. Fish greater than 12g fed the 27% protein for the last nine weeks grew at the highest rate among all six groups. In turn, the 27% protein diet, when fed to larger fish(>12g), produced more weight gain than the 50 and 40% protein diets fed to smaller fish(<12g).

Waller-Duncan's new Bayesian test (5% LSD) shows that there was no significant difference among the growth rates for the fish in the control groups fed three protein diets and larger fish fed

Table 3. Summary of Waller-Duncan Bayesian Test(5% level LSD) for the data for the last 9 weeks of the 20-week experiment. Mean weekly growth rate as % of the initial body weight was used as treatment mean.

	Protein level					
	50%	40%	27%	40%[1]	27%[2]	27%[3]
Weight (g)						
Initial	8.04	8.07	6.48	7.24	8.23	14.43
Final	11.82	11.39	8.54	9.75	10.20	21.90
mean weekly growth rate (%)	5.18	4.22	3.26	4.02	2.58	5.80
sample variance (s^2)	6.75	1.64	1.56	2.92	0.48	2.98
standard deviation (s)	2.60	1.28	1.25	1.71	0.69	1.73
standard error ($s_{\bar{x}}$)	1.16	0.57	0.56	0.76	0.31	0.77

LSD_{wd} (.05)=2.48

RANK:

27%[2]	40%[1]	27%	40%	50%	27%[3]
2.58	3.26	4.02	4.22	5.18	5.80

[1]For the fish transferred from 50% protein diet. [2]For the fish from 40% protein diet. [3]For the fish greater than 12g. [4]Means underscored by the same line are not significantly different.

27% protein diet(Table 3). However, the growth of fish transferred to 40% and 27% protein diets were significantly lower than those of fish under the 50% and larger fish on the 27% diet. The regression coefficient for the growth was highest in the larger fish fed the 27% protein followed by those of fish in the control groups. The early differences in growth efficiency between three protein diets were stabilized and became nearly identical after about ten weeks. This may indicate that the 50 and 40% protein diets do not have much advantage over the 27% protein diet in terms of conversion or growth efficiency after about ten weeks of rearing. Considering the fact that the 50 and 40% protein diets contain nearly twice and one and half times more protein than does the 27%, it was quite clear that the protein in the 50 and 40% diets were much less efficiently utilized when compared with the 27% diet. Therefore, the protein levels in the diet can be lowered at least to 27% without significant reduction in weight gains, after about ten weeks of rearing or when the young perch have reached around 12g. The size range or time for the shifting of protein level may vary to some extent, and thus require further verification. Yet the highest weight gain of larger fish(>12g) on the 27% protein among all groups indicates that the 27% protein level is sufficient enough for the normal growth, if not optimum, of the yellow perch.

Satia(1974) found that protein requirements of the rainbow trout dropped from 50 to 40% after six to eight weeks. In coho salmon smolt(about 14g), weight gain and protein retention levelled off after 40% protein in the diet was reached(Zeitoun *et al.* 1974). In the green sunfish, there was a decrease in protein utilization of about 1.2% per gram of body weight increase(Gerking 1952). The rate of decrease in the protein utilization by the yellow perch appeared to be much greater than

Gerking's sunfish, although they are not directly comparable to each other.

Fish can sustain the homeostatic body condition under a variety of feeding conditions(Brown 1946). Yet the protein needed for maximal growth is subject to considerable variations with other factors. Delong *et al.*(1958) found that the chinook salmon produced the highest weight gain at the 55 and 65% protein levels when temperature was 14℃, and it was at 40% level when temperature was 8℃. Optimum growth of the sockeye salmon occurred at 15℃ with excessive food, while it was at 5℃ when fed with a limited daily ration (Brett *et al.* 1969). Zeitoun *et al.* (1973) found that the minimum protein requirements of rainbow trout fingerlings were slightly lower (40%) at 10 ppt salinity than at 20 ppt(45%).

The efficiency of protein utilization in fish is dependent upon other supplemental energy sources such as fat and carbohydrate (or total energy content) of the diet. Phillips *et al.* (1966) could reduce the protein level from 27 to 18% in the trout diets without loss of growth by substitution of corn oil. Lee and Putnam(1973) replaced one-third of dietary protein level(from 53 to 36%) by using corn starch with no loss in weight gain in a high energy trout diet containing 24% of herring oil. The effects of carbohydrate on the protein conversion efficiency depend on the quantity of protein present in the diets. According to Nail(1962) the increase of carbohydrate from 9 to 19% resulted in improved efficiency of protein conversion only when the levels of protein in the catfish diets were low, 6 and 16%, while nearly no effect was found when the protein levels were high, 25 and 35%.

The efficiency of carbohydrate or fat in regard to protein sparing also depends on the digestibility or acceptability of these materials by fish. Phillips *et al.* (1966, 1967) reported that trout utilized maltose and spared protein. But when fed over 6% maltose in the diet the trout developed excess liver size and glycogen deposition which very often leads to severe mortality. The acceptable levels of carbohydrate, below which no deleterious effects occur, vary greatly ranging from as low as 6-12%(Phillips *et al.* 1948, 1966) to 45%(McLaren *et al.* 1947) in trout, and from 48%(Buhler and Halver 1961) to 63%(Delong *et al.* 1958) for salmon. Lee and Putnam(1973) found an increased amount of body fat with increasing dietary fat in the trout diet and reduced amount of body protein.

In the present study, about 23% of dietary protein was spared by using oat flour and lipid materials without any noticeable ill-effects or reduction in weight gains. Since no proximate analysis of body composition was performed, however, the true value of the protein sparing in the yellow perch by substituting inexpensive energy sources remains to be examined further.

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