NUTRITIONAL AND FEEDING VALUE OF A SALMON PROTEIN HYDROLYSATE IN DIETS FOR WEANLING PIGS

Final Report

February 1991

Prepared for:

Alaska Fisheries Development Foundation, Inc.
508 West Second Avenue, Suite 212
Anchorage, Alaska 99501
(907) 276-7315

by:

Fredric M. Husby
Agricultural and Forestry Experiment Station
University of Alaska Fairbanks
Fairbanks, Alaska 99775-0080
(907) 474-7188

This information was produced with funds provided through the Saltonstall-Kennedy program administered by the National Marine Fisheries Service under Cooperative Agreement #89-ABH-00008

NUTRITIONAL AND FEEDING VALUE OF A SALMON PROTEIN HYDROLYSATE IN DIETS FOR WEANLING PIGS

REPORT TO

ALASKA FISHERIES DEVELOPMENT FOUNDATION, INC.

February 28, 1991

F.M. HUSBY

Agricultural and Forestry Experiment Station

University of Alaska Fairbanks

INTRODUCTION AND JUSTIFICATION

Alaska's seafood processing industry has allowed a considerable amount of the fishery resource to be lost by not recovering the processing wastes. Although there are several methods of recovery for processing waste in a usable form, the predominant product in the world is fish meal. Meals are the common term of reference in the market and should be used for comparing the quality of other fish by-products. Fish meal is defined as "the clean, dried, ground tissue of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil" with limitations on water (<10%) and salt contents (AAFCO, 1988). Unlike the majority of U.S. (menhaden) and South American (anchovy and sardine) fish meals manufactured from fish specifically caught for that purpose, Alaska's meals have been produced from processing wastes of shellfish, salmon, halibut and groundfish.

From 1975 to 1987, annual fish meal production in Alaska from three meal reduction plants ranged form less than 2,000 to 6,000 tons. These plants only produced a small percentage of the potential resource. Alaska's potential meal production could be estimated from the acceptable biological catch for all species, with the wet waste produced from those species in a range of 30-80% and a meal recovery of those species from 15-30 percent. This potential production of meal and protein is approximately 450,000 and 254,000 tons, respectively (Meehan, Husby, Rosir, and King, Alaska's Billion Pounds of Protein, International Marine By-Product Conference, Anchorage, April 1991, in press). During the above years, the number of meal plants and meal production was low due to a combination of poor economics of recovery in relation to markets, meals of poorer quality produced from processing wastes rather than whole carcasses, seasonal production in plants that were capitalized and scaled in size for year around production, and lack of statewide environmental awareness or restrictions. However, with the Americanization of the groundfishery, fish meal production has increased significantly in the Aleutians. Since 1987, four shore-based and eleven floating meal producers have been constructed and are producing a high priced ($700-$1,000 ton) whitefish meal and have adequate amounts of processing wastes to meet the economy of scale for the construction of 400-600 ton per day meal plants.

Some advantages of meal production are that equipment is designed and available for large volume processing, that the product can be preserved and shipped in a dry state (7-10% water), and that the oil can be separated from the rest of the waste. Some disadvantages of meal production are: capital intensive, high energy requirement and costs, high heat of cooking and drying may lower both protein digestibility and quality, and meals may be high in ash content (this problem is associated with meal production from processing wastes from heads and racks).

In consideration of the above, meal plants are not the method of choice in some Alasakan locations. Seasonal fisheries and the need for low ash, variable oil, and/or high protein quantity and quality products for speciality markets (aquaculture, pet and livestock milk replacer diets) may be better suited to the production of fish protein hydrolysates. "Fish protein hydrolysates are generally considered to be the liquefied products obtained from fish by the action of proteolytic enzymes under accelerated conditions of digestion" (Mackie, 1982), the product is produced from clean, undecomposed, whole fish or fish cuttings and a majority of the information available concerning the nutritional quality of hydrolysates is on products produced from whole fish rather than processing wastes. There is a need for further study to determine not only processing procedure but the nutritional value of hydrolysates from fish processing wastes.

Hydrolysis processing is usually associated with the advantages of lower capital costs, lower energy costs, simpler operation, economies of scale for low tonnages of waste, lower heat for higher quality protein (lysine availability), and more effective separation of ash and oil. Some disadvantages are that the product has been marketed as a speciality product demanding a higher price and the sudden increase in hydrolysate products may reduce the selling price, newer technology has increased the complexity and capital costs, and poor markets for mineral or oil.

For the last two years, Alaska Fisheries Development Foundation has been involved in feasibility studies to determine the effectiveness and marketability of hydrolysates produced in Alaska by smaller primary seafood processors where meal plants are not feasible and the products are from processing wastes rather than whole fish or fish cuttings. These studies include production methods, defining products and their nutritional value, and testing the feeding value of some of these products. The Agricultural and Forestry Experiment Station at the University of Alaska Fairbanks has been testing fish meals as protein and energy sources in early-weaned pig diets and would be interested in comparing the effectiveness of fish hydrolysates in similar diets.

Early weaning of 3- to 4- week old pigs may improve sow productivity through increased pigs produced per sow per year. However, early weaning is often accompanied with the typical postweaning growth check that is characterized by low feed intake with poor energy and nitrogen digestibilities, poor growth with a loss of body fat and frequently associated with malabsorption and often diarrhea (Lecce et al., 1979; Owsley et al., 1986; Cera et al., 1988a). Increased dietary nutrient density with highly digestible feedstuffs (high quality protein and fat) may be a means to increase feed intake and maintenance of postweaning growth rate (English et al., 1978). Cera et al. (1988b; 1989a,b) reported that both diet dry matter and fat digestibility with improved absorption were enhanced by unsaturation of fatty acids (corn oil>lard>tallow). Therefore, the polyunsaturated fats of fish oils may be more efficiently utilized in starter pig diets. High quality protein and nutrient dense (high fat, 25-30%) supplements similar to that represented by the salmon head protein hydrolysate (currently produced by North Pacific Processors, Inc., Cordova) may simultaneously provide dietary protein and fat and therefore, simplify and improve diet uniformity of blend.

Little information is available in the literature concerning the utilization of a fish protein hydrolysate in starter pig diets. Several commercial products have recently become available that are utilized in weaner pig diets but most of the information is proprietary. However, one study at Kansas Sate University with a hydrolysate containing 84% protein and low ash and oil indicated that the addition of 3% to starter pig diets resulted in an

8-17% improvement in average daily gain (ADG) when compared to corn-soybean meal diets (Stoner et al., 1985). In the last 5 years, renewed interest in fish meal supplementation to starter pig diets has resulted in recommended levels for routine utilization. British workers demonstrated that the addition of 5% herring meal to either conventional or high nutrient dense diets for weanling pigs significantly lowered mortality and decreased the incidence of observed digestive disorders in both diets, as well as increasing the average daily gain and the feed conversion rates (Pike et al., 1984). Low (5-7 percent) and moderate (10-13 percent) fat fish and herring meals have successfully replaced skim milk and some dried whey in early-weaned pig diets (Gunter, 1987; Gjefsen et al., 1980). Fish meals produced in Alaska (Husby, 1987) represent potential protein and fat supplements for starter pig diets. All-barley starter pig diets containing 10 percent high -(6%) or low -(1.9%) salt Alaskan herring meal provided average daily gains and feed efficiency equal to a similar diet with soybean oil meal but slightly reduced growth and feed performance when compared to similar diets with corn (Husby, 1988). A similar study with all-barley diets and 0, 5, 10 or 13.5% salmon meal resulted in equal growth and feed performance up to the 10% level but reduced daily gains and average daily feed intake at the 13.5% level of supplementation (Husby, Hugh and Harrold, 1989). The utilization of a high-fat fish meal, black cod meal, was effective at the 10% levels of supplementation regardless of barley type (covered vs. hulless) (Husby, 1989). In a second trial with black cod meal supplemented at the 20% level, the average daily feed intake and daily gains of 28-day old starter pigs were significantly greater than or similar to diets supplemented with soybean meal and corn oil, canola meal + canola seed, and soybean meal + tallow (Husby, 1990; Husby et al., 1990).

The above levels represent considerably greater supplementation levels than recommended 10-25 years ago but are meals produced with more modern technology and preserved with antioxidant and therefore usually contain higher quality protein and fat. The potential feed utilization of a salmon head protein hydrolysate has yet to be determined but if similar to other reports concerning hydrolysates, the protein and fat should be of excellent quality. However, some references indicate that fish head protein is a lower quality than protein from other parts of the carcass. Therefore, this proposed study may determine the quality of the protein in salmon head protein hydrolysate.

OBJECTIVES

To evaluate the nutritional and feeding value of a high-fat salmon head protein hydrolysate in early weaned pig diets. The specific objectives are:

1. To determine the nutritional (chemical) value of a high-fat salmon head protein hydrolysate by analyzing the product and mixed diets for proximate and amino acid composition, fatty acid profile, free fatty acid, peroxide and total volatile nitrogen contents.

2 To determine the growth and feed performance of 4-week old starter pigs fed all-barley diets with soybean oil meal and corn oil supplements replaced by increasing levels of the high-fat salmon head protein hydrolysate.

EXPERIMENTAL PROCEDURE

Animals and general procedure. A 28-day feeding trial will be conducted with 60 crossbred, early-weaned pigs to compare the growth and feed performance of 28-day old pigs (approx. 14 lb.) fed different levels of protein and fat from a salmon head protein hydrolysate in all-barley based starter pig diets. Male pigs will be castrated prior to 14 - days of age and no litters will receive creep feed prior to weaning. Pigs will be weaned at 28 ± 3 days and allotted to dietary treatment on the basis of sex, weight and ancestry and will be confined to elevated decks in a confinement building. Each diet treatment will have a minimum of three replications of four pigs per replication per diet. Pigs and feed will be weighed weekly and weekly as well as the total 28-day period criteria will be used to calculate average daily feed intake (ADFI), average daily gain (ADG) and feed conversion (F/G).

Diets. Five diets will be fed in a ground, meal form and will be formulated to contain NRC (1988) levels of 20 percent crude protein, 1.1 percent lysine, 0.8 percent calcium, 0.65 percent phosphorous and all the required micro minerals and vitamins to be supplied from premixes to meet or exceed the requirements. In addition to barley, each diet will contain 20 percent dried whey and the two control diets will be balanced for crude protein with soybean oil meal (44% CP) and equalized to the low and high range of fat content of the test diets with 1.25 and 4.4% fat added as corn oil, respectively. the diets will be low oil control (LCO), high oil control (HCO), 5, 10, and approximately 17.6 percent salmon head protein hydrolysate (5-SHPH, 10-SHPH and 17.6-SHPH, respectively) (Table 1).

The salmon head protein hydrolysate was produced from pink salmon heads in a 1,000 lb. Advanced Hydrolyzing System, Inc. (AHS - Astoria, OR) hydrolyzer. The process involves grinding of raw material, heating with enzyme until a liquid, soluble state is attained, screening to remove bone (ash), pumped to evaporators, centrifuging to separate oil and discarding of the stickwater. The process allows recovery of a dry meal type product, bone and oil separation. The processing particulars of heating temperatures and time are apparently proprietary for AHS and AFDF personnel. The pink salmon head protein hydrolysate plus Santoquin was produced during the summer of 1990 and available for swine feeding trials contain approximately 10% moisture, 25% ether extract, 4% ash and 60 % crude protein on an 'as fed' basis. (Most of the information in this paragraph was obtained through personal communication with Mr. John Hewitt, North Pacific Processors, Cordova, AK.).

Chemical analyses. All ingredients and diets will be analyzed for dry matter (DM) at 105°C, crude protein (CP), ash, and ether extract (EE) according to AOAC (1980). Dietary acid detergent fiber (ADF) and neutral detergent fiber (NDF) will be determined according to Goering and Van Soest (1970) (All preceding analyses will be conducted at the Agriculture and Forestry Experiment Station service laboratory in Palmer, AK). Additional samples will be submitted to a commercial laboratory (for example: Hazelton or A & L) for amino acid, fatty acid, free fatty acid contents, and peroxide value (PO) and total volatile nitrogen (TVN).

Statistical analysis. Dietary treatment mean differences for growth and feed performance, will be tested by a one-way analysis of variance and Orthogonal comparisons (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Diet composition of the five test diets was based on the assumption that the salmon hydrolysate contained 60% protein and 25% fat. Proximate or chemical composition of two salmon head protein hydrolysates (one preserved with the antioxidant Ten-Ox and the second with exthoxyquin) and five test diets are listed in Table 2. North Pacific Processors, Inc. produced two hydrolysates. The first one contained the antioxidant Ten-Ox but was subsequently found that an inadequate amount of antioxidant was supplemented to the dry hydrolysate. Therefore, a second hydrolysate was produced and the antioxidant ethoxyquin was utilized at levels specified by the manufacturer. The second product was utilized in the pig feeding trials but a decision was made to also chemically analyze and evaluate the first hydrolysate in this study. Both hydrolysates are characterized by higher than acceptable moisture content, lower protein, greater fat and ash than estimated by staff at North Pacific Processors, Inc. The remaining discussion of nutrient content will only refer to the hydrolysate with ethoxyquin or that one utilized in the test diets.

The salmon head protein hydrolysate contained 9.9% water. Fish meals containing greater than 10% water are usually discriminated against in the market since moisture above 10% favors mold growth and clumping or hardening during storage. The product from North Pacific Processors, Inc. had extensive clumping with hard chunks 12 inches in length and 10 inches in diameter that would not completely break down in the feed mixer. The result was a mixed diet with chunks of hydrolysate 1-2 inches in diameter and therefore, the possibility of a nonuniformity in mixed diets. One test (10% hydrolysate) diet contained these balls of fish hydrolysate and a decision was to leave this diet in the study since the product as received from NPPI would be similar to one offered to the market.

The crude protein content was 54.7% and was significantly lower than the estimate of 60% CP. Feed brokers prefer fish meals with a minimum of 60% CP. The lower CP in their product did not reduce the protein in the test diets since the minimum of 20% CP to meet National Research Council requirements for weanling pigs was met in all diets (Table 2). Amino acid analysis has not been completed at this time and the lysine status is not known. The lower crude protein is inversely related to the greater than expected oil levels of 27.1% compared to the expected 25% oil. However, this low crude protein (54.7%) content may be acceptable to certain markets where the product would simultaneously and uniformly add protein and energy (oil) to diets. An example would be certain aquaculture and pet diets that are formulated with fish meal on a protein basis and then oil is added as a separate ingredient increasing the probability for diets not being uniformly mixed. The quality of the oil has yet to be determined and those results will be submitted as an addendum.

The ash content of 8.1% is at an acceptable level when salmon meals produced from salmon heads, blood and viscera contain approximately 21% ash. High ash contents limit the level of supplementation in diets. The calcium and phosphorus contents of .35 and .55%, respectively, support the thoroughness of the screening procedure to remove bone. Bone in fish by-products has a calcium: phosphorus ratio of 1.5:1 and is usually 5 and 3.5%, respectively. The inverse calcium to phosphorus and low total levels indicate the expected amount to be present in proteinaceous muscle tissue. The complete removal of bone from this product may not be desirable for marketing in livestock and pet feeds, since fish meals are often considered excellent sources of calcium and phosphorus in these animal diets. With the low calcium and phosphorus levels it was desirable to determine what minerals were present to constitute an 8% ash content. Additional analyses for magnesium, potassium and sodium indicated that the hydrolysate contained 1.39% sodium or a 3.55% salt equivalent. This salt level is considered marginally acceptable and if above 4% must be reported on the label. The high salt level would indicate that the raw product (salmon heads) were prepared or stored in a saltwater wash. A fresh water wash would significantly reduce this salt and ash content.

Formulated test diets (Table 2) met the requirements for protein, calcium and phosphorus. The ash contents are considered high for weanling pig diets but were equal across all five diet treatments. Since the main objective of the study was to compare this product to soybean oil meal as a protein supplement, the levels of 5, 10 and 17.6% replaced about 30, 60 and 100% of the supplemental protein from soybean meal. However, the 27% fat content increased the diet energy density with increasing levels of hydrolysate. Therefore, to compare the hydrolysate diets on an isoprotein, isocaloric level, two control diets with supplemental fat approxiamtely equal to the 5 and 17.6% diets were included in this study.

Growth and feed performance by week and the overall four-week feeding trial are reported in Table 3. Pigs were fed from 16 to 39 lbs. body weight. The only significant effects by week were present in week one for both average daily gain and feed conversion (F/G). Daily gains of the pigs on the 17.6% diet were significantly ($P<.05$) lower than the low corn oil control, 5 and 10% hydrolysate diets, respectively. Although no significant differences were noted during the first feeding week for average daily feed intake, the .94 lb/day of the 17.6% hydrolysate diet was the least of the five diets. Feed conversion data indicated a significant negative conversion for pigs during the first week post weaning for the 17.6% hydrolysate diet. This would indicate that some pigs within each replicate lost weight while others gained minor amounts. One of the keys to a successful early weaning pig program is to provide a highly digestible diet that will be readily consumed by these pigs. At the 17.6% level of supplementation the diet did not meet the requirements for improved intake since pigs were losing critical body weight.

Average daily gains of the pigs fed the 17.6% hydrolysate were significantly ($P<.05$) lower than the other four diets for the full four week post-weaning feed period (.71 to .89

lb/day, respectively, Table 3). Although not significantly (P>.05) different than the other four diets, the average daily feed intake for the total four week period was lower when compared to the mean of the other four diets (1.45 vs. 1.62 lb/day intake). The feed conversion or efficiency of feed converted to pounds of gain was poorest for the 17.6% diet at 2.06 lb feed/lb body weight gain. However, this was not a significant difference (P>.05). The lack of significant differences for average daily feed intake and feed efficiency to help explain the reduced gains for the 17.6% diet may have been due to the high within replicate variation. Some of this variation across replicates may have been due to incomplete mixing of hydrolysate diets formulated with clumped material. There was a nonsignificant tendency for gains and feed intake to decrease with increasing levels of hydrolysate. Earlier work with similar diets at the University of Alaska reported reduced daily gains and feed intake when salmon meal was included at the 13.5% level (Husby, Hugh, and Harrold, 1989). Both this hydrolysate and the salmon meal were produced from waste that contained predominantly heads with some blood and viscera. In several reports in the literature, other authors refer to the poor quality of fish meals produced from fish heads. Little quantitative data has accompanied those earlier statements and it was not clear if those authors meant protein quality or digestibility. Either reason could explain the poorer performance of the 17.6% hydrolysate diet and the chemical composition may provide the data to substantiate if the quality is reduced in salmon head protein but further studies would be required to determine if the digestibility is lower for head protein or if similar results occur in protein meals and hydrolysates produced from heads from other fish species or total wastes from those other species processed by hydrolysis.

CONCLUSION

Some recommendations can be made for both manufacturing and feeding of a salmon head protein hydrolysate. In manufacturing, attempts should be made to reduce moisture and salt in the final products by drying to 7% or less water and use a fresh water wash on the raw salmon heads. This should reduce the possibility of mold growth and clumping of material during storage. The reduced salt content may enhance feed intake by animals at high levels of diet supplementation. For livestock or pet markets some bone could be left in the product by changing the screen size and, therefore, furnish dietary calcium and phosphorus.

Within the constraints of this study, salmon head protein hydrolysate should be limited to 10% or less of early weaned pig diets. There may be an acceptable level between 10 and 17.6% but additional studies would be required to determine that new supplemental level. Salmon head protein hydrolysate similar to salmon meal has some inherent nutrient or chemical characteristics that limits its utilization as the sole replacement for soybean oil meal in early weaned pig diets. Hydrolysates from wastes of other species should be produced and tested since the results from the salmon heads may be significantly different from hydrolysates produced from processing wastes of other fish species.

LITERATURE CITED

AOAC. 1980. Official Methods of Analysis (13th. Ed.). Association of Official Analytical Chemists, Washington, D.C.

Assoc. of American Feed Control Officials. 1988. Feed Ingredient Definitions. IN: Feed Industry Red Book. Communications Marketing, Inc., Eden Prairie, MN. p. 48.

Cera, K.R., D.C. Mahan, R.F. Cross, G.A. Reinhart, and R.E. Whitmoyer. 1988a. Effect of age, weaning and postweaning diet on small intestinal growth and jejunal morphology in young swine. J. Anim. Sci. 66:574.

Cera, K.R., D.C. Mahan, and G.A. Reinhart. 1988b. Effects of dietary dried whey and corn oil on weanling pig performance, fat digestibility and nitrogen utilization. J. Anim. Sci. 66:1438.

Cera, K.R., D.C. Mahan, and G.A. Reinhart. 1989a. Apparent fat digestibilities and performance responses of postweaning swine fed diets supplemented with coconut oil, corn oil or tallow. J. Anim. Sci. 67:2040.

Cera, K.R., D.C. Mahan, and G.A. Reinhart. 1989b. Postweaning swine performance and serum profile responses to supplemental medium-chain free fatty acids and tallow. J. Anim. Sci. 67:2048.

English, P.R., S.G. Deligeorgis, F.M. Davidson, M.F.M. Dias, W.J. Smith, and V.R. Fowler. 1978. Evaluation of alternative diets and feeding systems for early weaned piglets. Anim. Prod. 26:398 (Abstr.).

Gjefsen, T., K.E. Gulbrundsen and J. Opstvedt. 1980. Herring type fish meal in diets for early-weaned piglets. 1. Effects of different sources and levels of dietary protein. Acta. Agric. Scand. 30:157.

Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, regents, procedures, and some applications). Agric. Handbook 379. ARS, USDA, Washington, D.C.

Gunter, K.D. 1987. IN: Fish Meal Flyer. April. Intern. Assoc. of Fish Meal Manufactures, London, England.

Husby, F.M. 1987. Alaskan Marine By-Products: Production and Utilization Alaska Marine Resource Quarterly. Second Quarter, Univ. Alaska Marine Advisory Program, Fairbanks, pp. 16-19.

Husby, F.M. 1988. W-166, All-barley starter pig diets containing high-and low-salt herring meal, Univ. of Alaska Fairbanks Agric. and Forest. Exptl. Stat. Misc. Publ. 88-1, 1987 Ann. Rpt. Fairbanks, pp. 20-21.

Husby, F.M. 1989. W-166, Hulless and covered all-barley starter pig diets containing black and grey cod fish meals. Univ. of Alaska Fairbanks Agric. and Forest. Exptl. Stat. Misc. Publ. 89-1, 1988 Ann. Rpt. Fairbanks, pp. 6-7.

Husby, F.M., W.I. Hugh, and R.L. Harrold. 1989. All-barley and Alaskan Salmon meal starter pig diets. Univ. of Alaska Fairbanks Agric. and Forest Exptl. Stat. Misc. Publ. 89-1, 1988 Ann. Rpt. Fairbanks, pp. 8-9.

Husby, F.M. 1990. W-166, Hulless and covered all-barley starter pig diets containing black and grey cod fish meals. Univ. of Alaska Fairbanks Agric. and Forest Exptl. Stat. Misc. Publ. 90-2, 1989 Ann. Rpt. Fairbanks, pp.17-18.

Husby, F.M., C.W. Newman, R.M. Beanes, R.E. Busch, D.M. Danielson, and D.C. England. 1990. Effects of supplemental protein and fat sources on performance of weanling pigs. Proc. West. Sect. Amer. Soc. Anim. Sci. 41:219.

Lecce, J.G., W.D. Armstrong, P.C. Crawford and G.A. Ducharme. 1979. Nutrition and management of early weaned piglets: liquid vs. dry feeding. J. Anim. Sci. 48:1007.

Mackie, I.M. 1982. General review of fish protein hydrolysates. Anim. Feed Sci. and Tech. 7:113.

NRC. 1988. Nutrient Requirements of Swine (9th Ed.). National Academy Press, Washington, DC.

Owsley, W.F., D.E. Orr, Jr., and L.F. Tribble. 1986. Effects of nitrogen and energy source on nutrient digestibility in the young pig J. Anim. Sci. 63:492.

Pike, I.H., M.K. Curran, M. Edge, and A. Harvey. 1984. Anim. Prod. 39:291.

Steel, R.G. and J.H. Torrie. 1960. Principles and Procedures of Statistics. New York: McGraw-Hill Book Co.

Stoner, G.R., J.L. Nelssen, and G.L. Allee. 1985. Fish protein hydrolysate may improve starter pig diets. Feedstuffs. Dec. 30. p.7.

TABLE 1. PERCENTAGE COMPOSITION OF EXPERIMENTAL DIETS[a,b]

	Control		Salmon hydrolysate		
Item	LCO	HCO	5	10	17.6
Ingredients					
Barley	49.35	45.10	53.50	55.95	59.70
Soybean meal (44%)	26.65	27.75	18.75	11.30	---
Salmon hydrolysate (60%)	---	---	5.00	10.00	17.55
Dried Whey	20.00	20.00	20.00	20.00	20.00
Corn oil	1.25	4.40	---	---	---
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00
Limestone	0.85	0.85	0.85	0.85	0.85
TM salt	0.40	0.40	0.40	0.40	0.40
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Antibiotic[c]	0.25	0.25	0.25	0.25	0.25
Calculated composition					
Crude protein	20.00	20.00	20.00	20.00	20.00
Lysine	1.15	1.16	1.11	1.08	1.03
Fat, supplemented	1.25	4.40	1.25	2.5	4.40
Fat, Total	2.54	5.63	2.54	3.82	5.60

a As fed basis with Salmon head protein hydrolysate plus Santoquin etstimated at: CP = 60.00%, Lysine = 3.5%; fat = 25%; $H2O$ = 10%; ash =4%; (J. Hewitt, personal communication, 9/6/90)

b LCO = Low corn oil; HCO = high corn oil; 5 and 10 are percent dietary levels of salmon hydrolysate and 17.6 represents all supplemental protein above whey is salmon hydrolysate.

c CSP-250.

TABLE 2. CHEMICAL COMPOSITION OF SALMON HEAD PROTEIN HYDROLYSATES AND DIETS[a]

Nutrient[b]	Hydrolysate		Control		Salmon hydrolysate		
	Ten Ox	Ethox	LCO	HCO	5	10	17.6
	%						
DM	92.6	90.1	91.2	91.1	92.1	91.8	91.9
CP	51.6	54.7	22.6	23.6	22.4	21.3	20.97
EE	33.6	27.1	2.3	5.4	2.8	3.8	5.7
ADF	.15	.08	4.32	3.93	3.29	2.64	1.57
Ash	7.0	8.1	8.2	8.2	9.0	9.1	7.0
Calcium	.32	.35	.93	.88	1.04	1.17	.82
Phosphorus	.57	.55	.75	.72	.75	.72	.63
Magnesium	.11	.10	---	---	---	---	---
Potassium	.71	.69	---	---	---	---	---
Sodium	1.36	1.39	---	---	---	---	---

[a] As fed basis.

[b] DM = dry matter; CP = crude protein; EE = ether extract; ADF = acid detergent fiber.

TABLE 3. EFFECTS OF SALMON HEAD PROTEIN HYDROLYSATE ON PERFORMANCE OF WEANING PIGS

	Control		Salmon hydrolysate			
Item	LCO	HCO	5	10	17.6	SE
No.	12	13	12	13	13	
Start wt., lb.	15.08	16.39	16.86	15.6	16.32	
Final wt., lb.	40.36	38.61	41.12	38.7	36.08	
Daily gain, lb.						
Wk 1	.41	.23	.36	.30	.12	.03
Wk 2	.86	.75	.62	.75	.74	.05
Wk 3	1.13	1.12	1.17	1.08	1.02	.05
Wk 4	1.33	1.45	1.32	1.31	.95	.09
Wk 1 to 4	.93[a]	.89[ab]	.87[ab]	.86[ab]	.71[b]	.04
Daily feed,lb.						
Wk 1	1.18	1.20	1.04	.97	.94	.06
Wk 2	1.11	1.08	1.10	.99	1.07	.05
Wk 3	1.81	1.79	1.79	1.86	1.80	.05
Wk 4	2.05	2.04	2.15	1.83	1.98	.08
Wk 1 to 4	1.71	1.53	1.69	1.56	1.45	.07
Feed-to-gain ratio						
Wk 1	3.22	5.33	3.62	3.70	-18.56	4.71
Wk 2	1.45	1.54	2.07	1.49	1.46	.12
Wk 3	1.79	1.60	1.73	1.95	1.78	.07
Wk 4	1.71	1.43	1.81	1.61	2.37	.16
Wk 1 to 4	1.83	1.72	1.94	1.82	2.06	.06

[a,b] Means in the same row with different superscripts differ (P<,05).