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Title: EVALUATION OF FISHERY BY-PRODUCTS AS SUPPLEMENTAL PROTEIN SOURCES FOR POULTRY AND SWINE

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R.O. Kellems

The nutritive values of two fishery by-products, i.e. fish protein hydrolysate (FPH) and liquefied fish (LF), were studied. Three trials using Hubbard broilers, and Yorkshire pigs (starter and grower phase) were conducted. The FPH was used in the broiler trial and LF in the swine grower trial as supplemental protein sources, that replaced partially the soybean meal protein. The FPH was used to completely substitute for the skim milk component in milk replacer for the pig starter trial. Sensory evaluation of the edible tissue was conducted at the end of the broiler and swine grower trials to evaluate the carcass quality changes associated with feeding fish-containing diets.

The FPH derived from four different substrates (Hake, Dover sole, Brown rock cod and Atlantic cod) were incorporated into diets to provide 5% of the total dietary protein in the broiler trial and compared to Herring meal and soybean meal diets. Mean body weight (MBW) and feed conversion (FC) were determined when chicks were 4 weeks of age. The MBW of chicks fed the Hake, Brown rock diets were lower (P<.05) than those fed the corn-soy, Herring and

Atlantic cod meal diets. However, FC was found not to be influenced (P>.05) by the supplemental protein sources. Edible tissue samples were subjected to a sensory evaluation. Fishy flavor and off-flavor were detected (P<.05) in carcasses of broilers fed Herring and Dover sole meal. Juiciness of meat was the same (P>.05) in all broilers receiving different diets.

LF, prepared from Dover sole fillet scraps, was formulated to provide 24% (7.4% LF) or 12% (3.4% LF) of the total dietary protein in the rations for the swine grower trial. Initial weight for pigs used in the grower trial ranged from 26-28 kg. Pigs receiving the diet containing 7.4% LF had lower FC (P<.05) and average daily gain (ADG) (P<.01) than either the 3.7% LF or control groups. Growth of pigs fed the 3.7% LF group was not different (P>.05) from the control group. Similar results were obtained from the sensory evaluation of the edible tissue. Flavor, juiciness and overall desirability of edible tissue from pigs finished on 7.4% LF diet were different (P<.05) from pigs fed either the 3.7% LF and control. No difference (P>.05) in carcass quality was observed between 3.4% LF group and the control group.

Milk replacer diets containing either skim milk or FPH contributed 20% of dietary protein, were fed to young pigs from 6.7 to 22.5 kg of body weight. FC and ADG were not different (P>.05) between groups. The scouring problem was more severe in FPH fed pigs. However, the nutritive value of fish protein was shown to be similar to milk protein in the milk replacer diet for piglets.

Based on the results of these trials, protein sources derived from fishery wastes can be effectively used as supplemental protein sources for poultry and swine. Adverse effects in carcass quality might be obtained if they are used at high levels.

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Head of Department of Animal Science

Redacted for Privacy

Dean of Graduate School

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Contribution of the Authors

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Evaluation of Fishery By-Products as Supplemental Protein Sources for Poultry and Swine

LITERATURE REVIEW

The use of fishery by-products in animal feeding application is not a new idea. In the early fourteenth century, a primitive form of fish meal is mentioned in Travels of Marco Polo (Windsor and Barlow, 1981). Fish is a well-known source of high quality protein. The crude protein contents of all fish species fall within 2% or 3% of 16% (Windsor and Barlow, 1981). The best species of fish yield only about 50% edible material in the form of fillet. The remainder, the frame, head etc. of the fish is almost as high in protein content as the fillet. Filleting and canning produce large quantities of damaged fish and off-cuts suitable for by-product manufacture. With proper handling, these wastes can be utilized as an economical protein source for animals.

The production of fish meal and oil is extensively used as an outlet for non-edible fish, but there are many other alternative by-products that can be derived from fish wastes. Fish protein concentrates (FPC), fish protein hydrolyzates (FPH), liquefied fish (LF) and fish silage are some of the alternative ways of using marine wastes.

In developing countries, FPC is considered an efficient protein supplement for combating human malnutrition. However, flavor, texture and aroma play a key role in its acceptability.
This makes the production of FPC for human consumption a rather complex process and the resulting production is, therefore, expensive.

On the other hand, FPC for animal use has no restriction to its odor and almost any process which produces a stable protein concentrate can be considered. The production principle of this type of FPC is similar to fish meal, except the bones are removed to reduce the ash content and increase the crude protein content. No new processing technology is involved and the cost is only slightly higher.

FPC is produced by a process employing proteolytic enzymes that are derived from vegetable or animal sources. The fish protein is liquefied by the enzymatic hydrolyzes of the protien into shorter peptide molecules which enables the bones to be removed by screening. The liquefied protein can then be dried and used as a supplemental protein source in speciality animal feeds (milk replacer, fish diets, etc.). The fish liquefaction process itself is inexpensive, but the drying process increases the production cost dramatically.

In the production of LF, intrinsic fish enzymes which are already present in the fish flesh or extrinsic enaymes are used to liquefy the raw materials. It is a simple process by which fish waste can be converted to a stable liquefied product, which eliminates the drying expense. The primary limiting factor associated with LF is its high moisture content which restricts the distance it can be transported and economically utilized as a supplemental protein source for animal feeding. About all the equipment needed is a grinder, mixing tank and mixing device. The processing of whole fish to meal is impractial where samll scale operations predominate. LF is particularly suitable for the utilization of fish waste.

Fish Protein Concentrate (FPC) and Fish Protein Hydrolyzate (FPH)

Fish protein hydrolyzates (FPH) are produced by enzymatically hydrolyzing the fish flesh away from other materials such as bone, fat and scales. In the hydrolysis process, pH, temperature, time of reaction etc. are controlled, so that the properties of the resultant product can be carefully selected. Dried FPH can also be considered as FPC. However, the raw materials for FPC manufacturing are better selected and the quality of the final product is more restricted. The FPC's are defined as those products obtained from fish in which the protein is more concentrated (bone removed), normally 60-88% crude protein, than in the original fish. It may be prepared by a variety of methods and most of which can be classified as chemical (solvent extraction) or biological (enzymatic and microbial) procedures.

FPC's are generally lacking in important functional properties such as dispersability, solubility in water, or emulsifying properties. Therefore, industrial acceptance is poor. To improve the quality, Opstvedt and Sobstad, 1975 developed a new processing method by which better water-holding and emulsification capacity of fish protein were obtained. In trials done by Opstvedt *et al*. (1978) they showed that when FPC with these improved function properties was used as a milk replacer, apparent protein digestibility was increased in the calves between 7-63 days of age. This makes FPC more competitive on the market. FPH is a water soluble hydrolyzed protein product produced from fish. The protein solubilities in water can be controlled to some extent by the conditions of the enzymatic treatment. It is difficult to give representative figures on the composition and quality criteria of FPH, since different processing techniques result in different end products.

In European countries, especially France, fish hydrolyzates have been used as milk replacers for some time. Tarky et al. (1973) reported that probably due to low level of tryptophane, FPH alone showed poor nutrition quality, but when FPH was mixed with casein (or other protein with excess tryptophane), the FPH gave Protein Efficiency Ratio similar to that of pure casein, reducing the cost of the milk replacer.

Soliman and Orskov (1979) observed that lambs on FPH performed less well during the first 15 days, but compensated during the next 18 days. After 30 days, there was an improvement in protein digestibility. Successful results had been obtained when up to 60% of milk protein was replaced by fish protein of calves who were 21 days of age (Windsor and Barlow, 1981). Huber and Slade (1968) and Raven (1972) found that apparent digestibility of fish protein to be low at 1-3 weeks of age and improve thereafter. In young ruminants the lack of clotting in the abomasum, along with possibly insufficient proteolytic activity in the abomasum, along with possibly reduced pancreatic proteolytic activity associated with feeding fish protein (Guilloteau et al., 1975; Ternouth et al., 1975) may have made the FPH less digestible.

FPC has been used in various parts of the world for several centuries. It has only been in the past 30 years, however, that the production of FPC has been investigated on a scientific basis (Knobl _et al_., 1972). Hale (1974) pointed out that the most promising application for biological FPC's was as a partial replacement for milk in the diets of weaner calves. Considerable research has been conducted evaluating the nutritive value of fish protein in milk replacer in pre-ruminants (Campos _et al_., 1981; Huber, 1975; Roy _et al_., 1977; Sleiman and Huber, 1971; Gorrill _et al_., 1975). Campos and Huber (1982) compared the protein from fish and soybean. The results showed that spray-dried fish solubles were inferior to milk protein or soybean protein concentrate for inclusion in milk replacers for calves. Huber and Slade (1968) observed that digestibility of dry matter and crude protein decreased as the amount of fish flour in milk replacer for calves increased. In the same report, however, data showed that fish flour could be used to furnish up to 40% of the dietary protein without reducing performance ($P>.05$) in average daily gains and feed efficiencies. Bauersfeld and Soares (1972) reported that low levels (5%) of fish soluble produced equal calf growth when they replaced a similar amount of milk products in calves, but not in high levels (15%). It was concluded that if significant quantities of fish protein were to be incorporated into milk replacer rations, protein of higher quality than that present in fish soluble must be used. The possible cause for the depressed growth when dietary protein containing high levels of fish protein was an imbalance of amino acids. Huston and Scott (1966) demonstrated that under certain conditions, excesses of both lysine and arginine were detrimental to chick growth.

In order to get the maximum productivity of breeding pigs, early weaning is required. However, owing to the particular physiology of the piglet at this age, the protein supply must be very digestible. With the excellent protein quality, fish protein may be considered as a replacement for the soy protein in milk replacers for swine. Pond et al. (1971) observed that protein of FPC was utilized efficiently by the baby pigs and was superior to that of soybean in pigs between 2-23 days of age.

Fish protein sources have been widely used in poultry diets. Harrison and Coates (1964) reported that the growth of chicks was improved by the supplement of 5% fish solubles in the diet; and the pattern of response to fish solubles was similar to penicillin. It was suggested that fish solubles might promote growth by modification of the alimentary microflora. This hypothesis was further proved by the same researcher (Harrison and Coates, 1972). However, the mode of action has not been clearly defined.

As a protein supplement for animal feed, the excellent amino acids content makes fish protein particularly effective in supplementing vegetable protein. Fish protein is high in lysine which, on the contrary, is the first limiting amino acid in cereal grains (Block and Mitchell, 1946; Yañez et al., 1967; Morrison and Campbell, 1960). Fortification of cereals with FPH increased in both quality and quantity of dietary protein (Yañez et al., 1976).

Fish Silage and Liquefied Fish (LF)

The concept of converting fish waste into fish silage was developed from the principal of preservation by acids, originally invented in the 1920's by A.I. Virtanen who treated green fodder with a mixture of sulphuric and hydrochloric acid (Disney et al., 1977). In the 1930's, Norwegians applied the term 'silage' both to fish and fodder which had been treated with acids as a preservative. Silage is a misnomer for in neither case is a true fermentative silage formed; the microbial population is actually decreased. In fish, the proteins slowly break down by autolysis forming increased amounts of soluble proteinaceous material. The term liquified fish (LF) is now replacing the term fish silage. In the 1940's, Edin carried out more work using sulphuric and hydrochloric acid and suggested a formula based on pH, protein and ash measurement to calculate the amount of such acid required by minced raw materials.

The main advantages of the LF process are: the low capital investment required; most of the work can be done by unskilled and semiskilled labor; the basic process is suitable for nearly any sized production. The process can be carried on at ambient temperature and the final product is stable for months, even years. The basic procedures for LF production include: mincing (raw material), acid treatment, mixing and liquefaction. Acids used for liquefaction can be mineral acids, certain organic acids or the combination of both. Pig feeding trials done by Lisac in 1961 indicated that the cheapest acid suitable for Mediterranean sardine offal was a mixture of 6:1 sulphuric acid/formic acid. Moreover, using a combination of sulphuric-formic acid mixture and preheat treatment in sprat silage preparation has been proven to reduce the degradation of oil in silage (Reece, 1980). The amount of acid required depends on the ash content of the fish and the type of acid used; higher ash content requires more acid (Green and Mattick, 1979). The details of the LF process has been described by Tatterson and Windsor (1974), Tatterson (1976) and Nicholson (1976).

LF has been experimentally fed to pigs, poultry, mink and cattle. The information that is available is too limited to draw firm conclusions about nutritive value of protein in LF. Because of its high moisture content (about 80%), LF should be dried or concentrated prior to feeding to poultry. In Europe, liquefied whole herring and groundfish (white fish) filleting wastes are fed in liquid form to pigs. The most suitable outlet of LF appears to be in pig farming, since it can be used in liquid feeding systems.

As judged by growth performances and carcass characteristics, LF made from white fish offal could be used as the sole protein source in fattening rations for bacon pigs (Luscombe, 1973). Few feeding trials have showed that pigs on the LF diet significantly increased the growth rates and feed efficiently as compared to soybean meal diets (Windsor and Barlow, 1981). On the contrary, Smith (1977) reported that pig performance was significantly reduced although an acceptable growth rate was obtained when LF was incorporated in fattening rations. However, trials showed no palatability problems with pigs and some advantage in handling the liquid product. Hillyer *et al.*(1976) reported that no acceptability problem was found when growing pigs were fed LF which occupied less than 15% of the diet dry matter.

Smith (1977) reported that tainted meat and unacceptable carcass were observed in pigs given herring LF, but not in those fed LF prepared from white fish at the same level (both were provided as the sole protein source). Whittemore and Taylor (1976) found that the quality of the herring silage as measured by the content of amino acids and available lysine appeared slightly superior to that of white fish meal. Thus the use of LF should not be limited providing it is included in rations on a least cost basis.

There were some other research works reported showing the successful feeding of acid LF to pigs and poultry (Sikorski *et al.*, 1969; Smith and Adamson, 1976). However, studies by Tarr *et al.* (1953) indicated that neither acid autolysis nor bacterial fermentation products prepared from whole herring promoted chick growth more effectively than did commercial herring meal. In another poultry trial, liquefied herring fish were compared with presscake herring meal, whole herring meal and condensed herring solubles as a supplementary protein. The results showed that liquefied herring meal gave intermediate values in feed efficiency between herring meal (best) and condensed herring solubles (McBride *et al.*, 1961). In ruminants, LF is an effective nitrogen source. It has a pleasant silage odor and has no detectable fish odor. Dry matter digestibility, nitrogen digestibility and N-retention were increased in lamb fed fish silage with wheat straw (Chirase and Males, 1982).

Kumar and Sampath (1979) reported that LF contained 19.41% DCP, 57.82 SE and 52.79% TDN (as DM basis) indicating that it could be a good source of protein and carbohydrates. In tropical countries, especially where expensive foods must be imported, LF mixed with carbohydrate materials to give a dry meal instead of liquid product could offer considerable benefits as a mean of converting waste fish into animal feed supplement. The LF/carbohydrate combination has proved to be a source of protein and energy for poultry (Disney et al., 1978).

Off-flavors Associated with Feeding Fishery Products

One disadvantage of feeding fishery products is the oil content, which may impart a "fishy" taint to the carcass when they are included above certain concentration in the diet. Dean et al. (1971) found that a broiler diet containing 19% fish meal produced a fishy flavor in the meat. This was reduced by allowing for a 72 hour period of starvation prior to killing. Similar observation reported by Opstvedt (1971) showed that no off-flavors were detected in the six-week-old chicks, but taint problems could easily occur in older birds.

Windsor and Barlow (1981) indicated that unless LF made from oily species were de-oiled, the meat of pigs fed LF could be tainted. However, it would be no problem if the total fish oil in the complete diet did not exceed 1% of the dry matter (Vestal et al., 1945), which was in agreement with Carpenter (1971) and Smith (1977). In the work reported by Shearer et al. (1970), fish meal could be incorporated into finishing diets up to 12% without causing any "fishy" taint in the bacon. Negative results were also reported by work using white fish meal (Orr et al., 1922; Edwards, 1929) and menhahen (Vestal et al., 1945).

By reducing the quantity of fish oil in the diet or by terminating the fish-contained diet for an interval of time before animals are marketed, tainted meat problems can be partly solved (Frazer et al., 1934). The technique of the withdrawal period is not always effective, especially when fairly high levels of fish oil have been fed.

The reasons which cause tainted meat when fish products are used are not yet completely established. Some researchers suggested that fatty acids of the ω3 family containing 18 to 22 carbon atoms are positively correlated with the incidence and degree of off-flavor in pig or broiler flesh (Miller et al., 1967; Kifer et al., 1971). These partially agreed with the hypothesis of Banks and Hilditch (1932), who indicated that the fatty acids of the C_{20-22} series commonly found in the oil associated with an off-(fishy) flavor. Kifer et al. (1971) further suggested that on a pratical feeding basis, fish oil with ω3 fatty acid composition consumption should be limited to 0.8% of the diet if fed until pigs were marketed.

Large amounts of non-edible fish are produced from seafood processing industries annually. Much effort has been devoted to the development of saleable by-products from these fishery wastes. Not enough technical information and assistance in utilizing fishery by-products as animal feed has been provided to the animal producers. More scientific data is needed to establish the nutritive value of these fishery by-products. Trials done here were designed to study the feeding values of by-products derived from underutilized fish, evaluate the carcass quality of animal fed fish-containing diets and determine the optimun level at which marine products could be incorporated into the rations.

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The Effect of Feeding Five Fish Meal Products on Broiler Performance and Carcass Sensory Characteristic[1]

Y.C. Wu[2], Z.A. Holmes[3], R.O. Kellems[2] and H.S. Nakaue[4]
Oregon State University, Corvallis 97331

Key Words: Fish meal, Herring meal,Hake (Pacific whiting), Fish by-product, Broilers

[1]Tech. Paper No. , Oregon Agr. Exp. Sta.
[2]Department of Animal Science
[3]Department of Foods and Nutrition
[4]Department of Poultry Science

The effect on feeding five fish meal products on broiler performance and carcass sensory characteristics

Y.C. Wu, Z.A. Holmes, R.O. Kellems, and H.S. Nakaue

ABSTRACT

Hubbard broiler chicks were fed to 7 weeks of age diets containing Hake (Pacific whiting), Dover sole, Brown rock, Atlantic cod and Herring meal, that provided 5% of the total dietary protein. No differences (P>.05) among the treatments were observed in average live body weight and feed conversion; however, mean dressed broiler weight (P<.05) was influenced by the type of fish meal. The diets significantly (P<.05) affected drip cooking loss, and the fishy and off-flavor sensory characteristics of the cooked broiler carcasses. There were no differences (P>.05) due to diet in total cooking losses, cooking time, total moisture and juiciness.

(Key words: Fish meal, Herring meal, Hake (Pacific whiting), Fish by-product, Broilers.)

INTRODUCTION

Fish meals and similar fish derived products have been regarded as good supplemental protein sources for poultry. Warnick and Anderson (1967) indicated that sulfur-containing amino acids were found to be the most limiting in corn-soybean meal diets. This condition can be corrected by replacing a portion of the protein provided by soybean meal with a portion derived from fish. The literature concerning the use of fish meal has been extensively reviewed by Harms et al. (1961), Rand et al. (1958), Waldroup et al. (1965) and Anderson et al. (1968). Fish meal has long been considered to contain unidentified growth factors which promote the growth of birds (Waldroup et al., 1967; Harrison and Coates, 1972; Avila and Balloun, 1974). The nature of unidentified growth factors, so far, has not been properly described. Because of the cost, undesirable off-flavor meat and growth depression effects caused by a high level of fish meal in broiler rations, the amount of fish meal is usually limited. The fishy flavor problem was reviewed (Fry et al., 1965; Waldroup et al., 1965; and Carlson et al., 1957). Waldroup et al. (1965) reported that body weight and growth were depressed when the use of fish meal was too high or when fish meal was used as the sole protein source (Schumaier and McGinnis, 1969). Fish meal is used mostly in rations fed to broiler chicks and to turkey poults. The commercially available fish meals are made from different species of fish using various production systems. Different fish meals vary in their feeding value. In this experiment, four different fish hydrolyzates and Herring meal were used to provide supplemental protein for corn-soybean meal based rations. This allowed for the evaluation of the feeding characteristics of several fish derived products. A sensory test was also conducted on the edible tissues obtained from broilers maintained on these various treatments.

MATERIALS AND METHODS

Commercial hatching eggs from a hatchery were purchased and hatched by standard incubation practices at the Department of Poultry Science, Oregon State University. The day-old chicks were feather sexed and randomly distributed, 5 males and 5 females per pen, with 4 pens per treatment. The composition and calculated analyses of the test diets are shown in Table 1. The diets were formulated to be isonitrogenous and isocaloric. Each diet contained different fish hydrolyzates or meal which provided 5% of the total dietary protein. Four commercially produced fish hydrolyzates were used: Hake (*Merluccius productus*), Dover sole (*Glyptocephalus zachirus*), Brown rock (*Sebastes entomelas*), and Atlantic cod (*Gadus morhua*). These products and Herring meal (*Clupea harengus pallasi*) were incorporated into the diets at the following levels: 5.66%, 7.0%, 5.63%, 5.12% and 6%, respectively. The protein and energy content of fish meals are shown in Table 2. The fish hydrolyzates were all prepared by enzymatically hydrolyzing the fish sources and bones were removed by subsequent screening. The resultant product was spray dried, except for the Dover sole which was sonically dehydrated.

Chicks were housed in electrically heated battery brooders

(Wes-built Battery Powered, Hayward, CA.). Each bird was wing banded and weighed individually at the beginning, 2 and 4 weeks of age. Feed and water were supplied *ad libitum*. Feed consumptions were determined at 2 and 4 weeks of age.

At the end of 4 weeks, six broilers were maintained on the Hake, Dover sole, Herring meal, Atlantic cod diets, and fifteen broilers were maintained on Brown rock and control diets to 7 weeks of age; then the birds were sacrificed for sensory evaluation. They were dressed, frozen and stored for 6 weeks until prepared for sensory testing. At testing time, the frozen birds (-15°C) were defrosted 1 hour at 25°C and 15 hours at 5°C.

Tissue moisture content was determined according to the AOAC oven method (Horwitz, 1980). Duplicate 5 g liquid nitrogen-powdered broiler meat samples from each replication and treatment were dried in an oven (Napco Oven, National Appliance Co., Portland, OR.), which was connected with a Cenco vacuum pump (Cenco Vacuum Pump, Central Scientific Company, Chicago, IL.). Drip and total cooking losses and cooking time of the roasted broilers was determined.

Broilers were roasted in a preheated 190°C gas oven until the center of the pectoral muscles reached 85°C. Sensory evaluation and total moisture determinations were performed on the outer pectoral muscle of each broiler. Fishy flavor, off-flavor and juiciness were evaluated by a trained panel consisting of 10 members. A seven-point scale was used with one being the least fishy, no off-flavor and juiciest and seven being the most fishy, off-flavor and driest.

The experimental data were subjected to a one-way analysis of variance and significant differences between treatment means

(P<.05) were separated by the multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Mean body weight gain, feed conversion, incidence of perosis and mortality at four weeks of age are presented in Table 3. No differences (P>.05), among the dietary treatments in male and female body weight gains and feed conversion were observed. However, the combined body weights of the broiler chicks fed diets containing Brown Rock and Hake meal had significantly (P<.05) smaller body weight gain than the chicks fed diets containing corn-soybean, Herring meal and Atlantic cod diets. The occurrences of perosis in Herring, Brown rock, Hake and Atlantic cod groups were higher (P<.05) than that in control and Dover sole groups. Mortality of birds given Hake was lower (P<.05) when compared with the birds fed other rations.

Sensory study on the carcasses is presented in Table 4. Percent cooking drip loss was greater (P<.05) for those broilers fed Dover sole than those fed Hake or the Atlantic cod containing diets. The broilers fed the corn-soy and other fish meal diets were not different (P>.05) from Hake fish meal. Further analysis indicated Dover sole and the corn-soy diet had greater (P<.05) drip cooking losses than broilers fed Hake fish meal. The Hake, Herring, Atlantic cod, and Borwn rock fed broilers did not differ (P>.05) in percent drip loss. There were no differences (P>.05) in total cooking losses, cooking time and total moisture content among the dietary treatments.

The diet eaten by the broilers significantly (P<.05) influenced the fishy and off-flavor parameters. Fishy flavor was greater ($P<.05$) for broilers fed Herring and Dover sole fish meal than those fed the other diets. The fishy flavor of the Herring over the Hake is different from that reported in the eggs from hens fed Hake meal. The eggs from hens fed Hake meal were generally lower in flavor acceptability than those from eggs of hens fed Herring (Koehler and Bearse, 1975). There was no difference ($P>.05$) in fishy flavor for broilers fed Herring versus Dover sole containing diets. No differences in fishy flavor of the cooked carcasses ($P>.05$) were found between the corn-soy fed diet and Atlantic cod, Hake, and Brown rock fish meal diets.

The second flavor characteristic, off-flavor, was greater ($P<.05$) in carcasses of broilers fed Herring and Dover sole meal containing diets than the corn-soy, Hake meal and Brown rock diets. The broilers fed Dover sole had a greater ($P<.05$) off-flavor than the Herring diet. The corn-soy diet, Hake, Atlantic cod, and Brown rock fish meal broilers did not differ ($P>.05$) in off-flavor. There were no significant differences in juiciness of meat from broilers fed the five fish meal diets.

These observations on sensory characteristics would emphasize the necessity of doing such evaluation with each type of fish meal product used in feeding studies. The type of product not only significantly influenced initial weight and drip cooking losses; but it also influenced the off- and fishy flavor.

On the basis of these results, it appears that fishery products prepared from different substrates and processing procedures resulted in the different carcass quality even when they were incorporated into broiler diets to supply the same quantity of dietary protein. Differences were observed in dressed weight of chicks slaughtered at 7-week-age. However, feed conversions of birds at 4-week-age were not influenced by the fish protein sources. Level of fishery products used in diets should be carefully formulated to prevent the adverse effects they may have on the broiler edible tissue.

Table 1. Composition of broiler diets

	Corn-soy	Herring	Dover sole	Brown rock	Hake	Atlantic cod
	%					
Corn	55.81	62.94	61.85	63.36	63.83	64.42
Fat	5.0	2.68	2.36	2.62	2.17	2.14
Soybean meal, 47.5%	34.2	23.68	23.86	23.50	23.35	23.36
Herring meal[1]		6				
Dover sole			7			
Brown rock				5.63		
Hake					5.66	
Atlantic cod						5.12
Dehy. alfalfa meal, 17%	2.0	2.0	2.0	2.0	2.0	2.0
Defluo. phosphate	1.8	1.5	1.72	1.72	1.72	1.72
Limestone flour	0.5	0.5	0.63	0.63	0.63	0.63
Salt (iodized)	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineralized mix[2]	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin mix[3]	0.20	0.20	0.20	0.20	0.20	0.20
d, l methionine (98%)	0.19	0.20	0.08	0.14	0.14	0.21
Calculated analysis:						
Crude protein, %	21.6	21.5	21.5	21.5	21.4	21.5
Met, energy Kcal/kg	3136	3138	3138	3138	3138	3138
Calcium, %	.91	.92	.92	.96	.92	.92
Avail, phos., %	.45	.47	.46	.45	.41	.45
Lysine, %	1.17	1.21	1.63	1.48	1.48	1.16
Methionine, %	.53	.55	.61	.62	.62	.61
Cystine, %	.37	.36	.36	.35	.35	.34
Meth, + Cys., %	.90	.91	.97	.97	.97	.95

[1]Provided gratuitously by Moore-Clark Co., LaConner, WA.

[2]Supplies per kilogram of feed: calcium, 97.3 g; manganese, 60 mg; iron, 20 mg, iodine, 1.2 mg; zinc, 27.5 mg; cobalt, 0.2 mg.

[3]Supplies per kilogram of feed: vitamin A, 3300 IU; vitamin D_3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 mg; vitamin E, 1.1 IU; vitamin K, 0.55 mg; folacin, 0.22 mg.

Table 2. Protein and energy level in fish hydrolyzates and Herring meal

Fish products	ME, kcal/kg	CP, %
Dover sole	3635	61.3
Brown rock	3356	76.4
Hake	3409	75.9
Atlantic cod	3450	84.0
Herring	3584	82.0

Table 3. Mean body weight gain, feed conversion, incidence of perosis and mortality at four weeks of age[a,b]

Dietary treatments	Mean body weight gain			Feed conv.	Mean perosis, %	Mean mortality, %
	Male	Female	Male + Female			
	g	g	g			
Corn-soy	916[a]	820[a]	868[b]	1.70[a]	5.00[a]	7.50[b]
Herring	929[a]	814[a]	872[b]	1.63[a]	10.00[b]	2.50[b]
Dover sole	902[a]	771[a]	836[ab]	1.65[a]	0.00[a]	10.00[b]
Brown rock	848[a]	754[a]	801[a]	1.68[a]	20.00[b]	7.50[b]
Hake	849[a]	792[a]	821[a]	1.71[a]	15.00[b]	0.00[a]
Atlantic cod	882[a]	801[a]	841[b]	1.63[a]	17.50[b]	5.00[b]

[a,b]Value in each column with different superscripts are different ($P<0.05$).

Table 4. Mean values of objective and sensory data of thawed frozen, roasted broilers fed five different fish based diets[1]

	Dietary treatments					
Parameter	Corn-soy	Hake	Herring	Atlantic cod	Brown rock	Dover sole
Initial weight (g)	1234.4^{a}	941.2^{b}	1080.2^{a}	976.5^{a}	1138.4^{ab}	1120.1^{ab}
Cooking losses drip (%)	10.2^{ab}	6.0	9.0^{abc}	6.89^{bc}	8.3^{abc}	11.0^{a}
Cooking losses, total	22.6^{a}	22.2^{a}	24.7^{a}	23.9^{a}	22.8^{a}	23.1^{a}
Cooking time, (min/g)	0.057^{a}	0.059^{a}	0.054^{a}	0.064^{a}	0.060^{a}	0.053^{a}
Total moisture (%)	69.2^{a}	69.6^{a}	68.6^{a}	69.8^{a}	69.4^{a}	68.9^{a}
Fishy flavor[2]	1.5^{a}	1.4^{a}	4.1^{b}	2.3^{a}	1.3^{a}	3.9^{b}
Off-flavor[3]	2.1^{b}	2.0^{b}	3.5^{a}	2.5^{b}	2.0^{b}	3.6^{a}
Juiciness[4]	3.4^{a}	3.9^{a}	3.2^{a}	3.1^{a}	3.8^{a}	3.5^{a}

[1]Means with the same letters in each row are not different ($P>.05$).
[2]Fish flavor (1 = no fishy-flavor, 7 = very fishy-flavor).
[3]Off-flavor (1 = no off-flavor, 7 = very off-flavor).
[4]Juiciness (1 = very dry, 7 = very juicy).

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Evaluation of Liquefied Dover Sole Fillet Scraps as a Supplemental Protein Source for Swine[1]

Y.C. Wu[2] and R.O. Kellems[2]

Key words: Fish by-product, Protein source, Swine

[1]Oregon Agricultural Experiment Station Technical Paper No. 6787.
[2]Department of Animal Science

Evaluation of Liquefied Dover Sole Fillet Scraps as a Supplemental Protein Source for Swine

Y.C. Wu and R.O. Kellems

SUMMARY

Liquefied fish (LF) prepared by enzymatically hydrolyzing and stabilizing Dover sole fillet scraps was evaluated as a supplemental protein source for use in finishing swine rations. The LF contained 45.1% dry matter, 20.1% crude protein, 37.5% ether extract, 2.25% Ca,.55% P and had a pH of 3.5. Seventy-two purebred Yorkshire feeder pigs were randomly allotted by weight to groups of six pigs each, with four groups being assigned to each of the following treatments; 1) corn-soybean meal control; 2) corn-soybean meal + 7.4% LF; and 3) corn-soybean meal + 3.7% LF. Initial average weights for groups ranged from 26.3 to 27.5 kg per head. The trial was terminated when the animals weighed 68.1 kg. At the conclusion of the performance trial two pigs were continued on each of the respective diets until they weighed 100 kg and then slaughtered; another two pigs from the LF groups were placed on the control diet and fed to 100 kg. The edible tissues from these five treatment groups were then evaluated by a taste panel. Average daily gain (ADG) and feed efficiency (FE) were lower ($P<.05$) for the 7.4% LF groups as compared to the 3.7% LF and control groups. No differences ($P>.05$) were observed between the 3.7% LF and control groups for ADG or FE. Taste panel scores for flavor, juiciness and overall desirability were lower ($P<.05$) for pork chops from pigs fed to 100 kg on the diet containing 7.4% LF as

compared to control or 3.7% LF. No differences (P>.05) were observed between the 7.4% and 3.7% LF groups that were switched to the control diets at 68.1 kg and the control animals. These results would indicate that LF can be utilized as a supplemental protein source for swine, but if marine oils were present a withdrawal period would be required in order to prevent tainting of the edible tissues.

INTRODUCTION

Approximately one-third of the world's total catch of fish is not used for human consumption, but is wasted or used for the production of fishery by-products (Windsor et al., 1981). Production of fish meal and oil has long been the most common by-product produced from these non-edible fishery wastes. However, some situations exist that make the processing of fishery wastes into fish meal impractical. For example, there may be no fish meal plant close to fish processing plants or the lack of reasonable transportation to the nearest plant. In some areas, the sources for raw materials are so variable or small that it is not economical to justify the capital investment for a fish meal plant.

An alternative method of converting fishery wastes into a marketable by-product is the production of liquefied fish (LF). The production of LF has lower capital investment requirements for processing equipment and produces a product of higher nutritional value. Liquefied fish is produced from fishery processing wastes, underutilized species of fish or from incidental catches of fish; these substrates are enzymatically digested under controlled pH and temperature conditions and then stabilized to allow the LF to be stored under ambient conditions (Kellems et al., 1980). Fish silage is a similar product that is produced under less controlled conditions. Feed conversion and carcass quality were found not to differ ($P>.05$) when 46.32% and 32.63% of fish silage levels were compared to a 7.5% fish meal group in swine (Luscombe, 1973). McBride et al. (1961) reported that feed efficiency for liquefied herring was better than that of condensed herring solubles, but inferior to pressed and whole herring meals when used as a supplementary protein source for poultry.

MATERIALS AND METHODS

Liquefied Fish

Liquefied fish (LF) used in this trial was prepared by enzymatically liquefying ground Dover sole (*Glyptocephalus zachirus*) fillet scraps, that had the pH adjusted to 3.5 with phosphoric acid, with intrinsic enzymes at between 50-55°C. After the proper degree of liquefaction was achieved the temperature was raised to 85°C to inactive enzyme systems and stabilized with 0.1% potassium sorbate to inhibit microbial growth. The resultant LF was then vacuum concentrated to produce a product that contained 45.1% dry matter, 44.5% crude protein, and 37.5% ether extract, expressed on a dry matter basis as determined using AOAC methods (1980). Composition is given for LF in Table 1. LF was stored under ambient conditions until used in the swine performance trial.

Diets

LF was incorporated into diets to replace soybean meal and replaced 24% in the 7.4% LF diet and 12% in the 3.7% LF diet of the total diet's protein. Corn-soybean meal diet was used as a control. Diets, as meal form, were formulated to be isonitrogenous (16% CP) and isocaloric (3650 kcal/kg, metabolizable energy); composition is given in Table 2.

Performance Trial

Seventy-two purebred Yorkshire pigs with an average initial group weight of 26.3-27.5 kg were used; with four replicates of 6 pigs (3 females and 3 castrated males) placed on each treatment. Pigs were allocated randomly by weight to the treatment groups. Pigs were housed indoors and feed was provided ad libitum, using self feeders, during the trial period. Water was available free choice using nipple type drinkers. Individual animal weights were determined weekly and pigs were terminated when they weighed 68.1 kg.

Edible Tissue Sensory Evaluation

After completion of the performance trial, two pigs from the three treatment groups were maintained on their respective diets until they reached market weight (100 kg). In addition, two pigs from the 7.4% and 3.7% LF were changed to the control diet at 68.1 kg and fed the control diet until they weighed 100 kg. Animals were then slaughtered and pork chops from the loin section were evaluated by a taste panel. Tenderness, flavor, juiciness, and overall desirability were determined for the edible tissue samples. Scoring was on an eight-point scale, with 1 = least desirable and 8 = most desirable for the parameters measured. A standard sample with a reference score of 5 was provided each taste panelist.

Statistical Analysis

All data was subjected to an analyses of variance (Steel and Torrie, 1960) and significant differences between treatment means ($P<.05$) were determined using the Duncan Multiple-Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Performance Trial

The average initial weight, feed conversion (FC) and average daily gain (ADG) are listed in Table 3.

The FC for pigs receiving the 7.4% LF diets was different (P<.05) than the control group (3.16 vs 3.02). Pigs fed the 3.7% LF diets required less feed (P<.05) than those on the 7.4% LF diet (3.16 vs 3.33). This agreed with Carr (1971) who found that feed required per unit of gain was increased as fish silage replaced other protein sources in finishing pig diets. Tibbetts et al., (1981) found that when ensiled waste fish (from shrimp boats) was fed to finishing pigs, diets containing higher level of ensiled fish caused a decrease (P<.05) in FC. ADG in corn-soybean control and 3.7% LF groups were not different (P>.05). The 7.4% LF group ADG was reduced (P<.01) as compared to the soybean-corn control and 3.7% LF groups. As the amount of LF in the diet increased ADG tended to decrease, which in part could be related to the differences in crude protein content of the diets (table 2).

Edible Tissue Sensory Evaluation

Differences (P<.05) in flavor, juiciness and overall desirability were detected in pork chops from pigs finished on the diet containing 7.4% LF (table 4). Pigs that were changed at 68.1 kg from the 7.4% LF to the control diet and finished (100 kg), showed no differences (P>.05) in flavor, juiciness or overall desirability when compared to the control. This indicates that withdrawing the animals from LF containing diets can prevent the carry over of undesirable tastes into the edible meat. No off-flavor was detected in the meat of the pigs fed diets containing 3.7% LF. There were no differences (P>.05) in tenderness observed between the tissue samples evaluated. This agrees with the work of Albrecht and Gebhardt (1969) that showed it was more important to restrict the pig's daily portions of fish products during the finishing period than to withdraw the fish products from the diets a few weeks prior to slaughtering. The oil content of the LF that is responsible for the tainted meat; unless the LF is de-oiled the meat will be tainted (Windsor et al., 1978). Kifer et al. (1971) indicated that feeding a diet containing 1% manhaden oil resulted in fishy flavor in the edible tissue of pork. In this study, however, the edible tissue flavor was not affected by the incorporation of 3.7% LF, which would have contributed .63% marine oil to the diet. The lipids responsible for the tainted flavor of pigs fed marine oils are thought to be associated with the long-chain polyunsaturated fatty acids of the w3 series (Miller et al., 1967), which are high in all marine oils. Tibbetts et al. (1981) found no changes in the acceptability of pork fed ensiled waste fish. Several other researchers have found no differences in the odor or flavor of pork from pigs fed white fish silage (Smith, 1976; Van Wyk et al., 1977).

These results would indicate that LF can be effectively utilized as a supplemental source of protein for finishing swine, but if excess marine oils are present in the LF that a reduced dietary level or withdrawal period would be required in order to prevent tainting of the edible tissues.

Table 5. Proximate analysis of liquefied fish

Item	As is basis
Crude protein, %	20.1
Ether extract, %	16.9
Calcium, %	2.25
Phosphorus, %	0.55
Dry matter, %	45.1
pH	3.5

Table 6. Composition of swine grower diets[a]

Ingredient	Control	Corn - SBM + 7.4% LF	Corn - SBM + 3.7% LF
	%		
Corn	82.6	84.5	84.0
SBM	14.4	7.0	10.3
LF		7.4	3.7
Tallow	.20		.09
Limestone	1.07		.47
Dical. Phos.	.74		
Vitamin premix[b]	.28	.30	.29
TM salt	.56	.6	.58
Antibiotic (CSP-250)	.11	.12	.12
Zinc sulfate	.04	.046	.47
Vitamin E	.002	.002	.002
Chemical composition[c]			
Crude protein	14.43	13.89	13.85
Energy (ME, Kcal/kg)	3617	3641	3626
Ether extract	2.60	3.30	2.80

[a]Expressed as a DM basis.

[b]Per kg contains: Vitamin A, K,333,333 USP Units; Vitamin D_3, 444,444 IC Units; Vitamin E, 444 I Units; Vitamin B_{12}, 4 mg; Vitamin K (MSBC) 889 mg; riboflavin, 1778 mg; pantothenic acid, 3,244 mg; niacin, 8,889 mg; choline chloride, 111,111 mg; selenium, 40 mg; and ethoxyquin, 2522 mg.

[c]Expressed on a DM basis.

Table 7. Swine performance trial summary

Group	Average initial wt. (kg)	Feed conversion	Average daily gain (kg)
Control corn-SBM	27.5	3.02[a]	.69[c]
Corn-SBM-3.7% LF	26.3	3.16[a]	.65[c]
Corn-SBM-7.4% LF	26.2	3.33[b]	.56[d]

[a,b]Means with different superscripts are different ($P<.05$)

[c,d]Means with different superscripts are different ($P<.01$).

Table 8. Sensory evaluation summary for pork chops from pigs fed liquefied fish

Diets	Tenderness[1]	Flavor[2]	Juiciness[3]	Overall desirability[4]
Control corn-soybean meal	4.5^{b}	5.1^{b}	4.7^{b}	5.1^{b}
Control + 7.4% LF, finished on diet	4.6^{b}	3.9^{c}	4.2^{c}	3.9^{c}
Control + 7.4% LF, changed to control diet at 68.1 kg	5.0^{b}	5.0^{b}	4.7^{b}	5.0^{b}
Control + 3.7% LF, finished on diet	5.1^{b}	5.1^{b}	4.9^{b}	5.3^{b}
Control + 3.7% LF, changed to control diet at 68.1 kg	4.5^{b}	5.5^{b}	5.2^{b}	5.6^{b}

[a]Fifty-eight evaluations per sample were determined by the taste panel.
[b,c]Means with different superscripts in same column are different ($P<.05$).
[1]Scored as 1 = extremely tough, 8 = extremely tender.
[2]Scored as 1 = least desirable, 8 = most desirable.
[3]Scored as 1 = extremely dry, 8 = extremely juicy.
[4]Scored as 1 = least desirable, 8 = most desirable.

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Fish Protein Hydrolyzate as a Supplemental Protein Source in Milk Replacer for Piglets[1]

Y.C. Wu[2] and R.O. Kellems[2]
Oregon State University

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[1]Oregon Agricultural Experiment Station Technical Paper No.
[2]Department of Animal Science

Fish protein hydrolyzate as a supplemental protein source in milk replacer for piglets

Y.C. Wu and R.O. Kellems

SUMMARY

Fish protein hydrolyzate (FPH) derived from Atlantic cod was evaluated as a substitute protein source in milk replacer diets for young pigs. Thirty pure bred Yorkshire piglets were on trial from 6.7 to 22.5 kg. Skim milk was used in the control diet to compare with the fish protein. Individual weights were recorded weekly and feed consumption records were also maintained. Feed conversion (FC) and average daily gain (ADG) in FPH fed pigs were similar (P>.05) to that fed skim milk (1.90 vs 1.97, .374 vs .369, respectively). No adverse effects were observed when FPH replaced skim milk in the piglet milk replacer.

INTRODUCTION

The idea of utilizing milk replacers can be traced back to early 1900's (Bauersfeld and Soares, 1972). Skim milk was the first supplemental protein source used in milk replacers. The high cost of milk protein led to a research for cheaper alternative sources. Soybean protein has shown the greatest potential for applications in milk replacers. The utilization of soybean protein by neonate has been thoroughly studied (Walker and Kirk, 1975; Maner et al., 1961; Schenider and Sarett, 1969; Sissons et al., 1979; Pelaez and Walker, 1979). However, the inferior utilization of soybean protein as compared with milk protein by baby pigs suggests that addition of alternative protein sources need to be evaluated.

The utilization of fish protein by preruminants has been an area of active researched (Bauersfeld and Soares, 1972; Raven, 1972; Soliman and Orskov, 1979; Campos and Huber, 1982). Trials done by Gorrill et al. (1975) indicated that fish protein concentrate (FPC) could be a useful ingredient in calf milk replacer. However, protein digestibility for FPC in calves was 10 to 30% lower than for dried skim milk (Huber, 1975). Huber and Slade (1968) reported that the digestibility of crude protein decreased as fish flour in milk replacer increased. Depressed growth was observed when fish flour furnished over 60% of the dietary protein to calves. But FPC with improved functional properties (i.e. water holding and emulsification capacity) could be fed as the principal protein source to calves from 3-62 days without causing digestive problems (Opstvedt *et al.*, 1978).

Limited work has been done with piglets. Leibholz (1982) found that piglets fed a soybean meal based milk replacer were depressed as compared to a fish meal based milk replacer for both weight gain (191 g/day vs 200 g/day) and feed conversion (1.10 vs 0.93), respectively. Pond *et al.* (1971) reported that FPC fed piglets gained 57 g/day as compared to 44 g/day for isolated soybean protein supplemented piglets. Live-weight gain of pigs were increased by 36 g/day when half the skim milk was replaced by FPC yet the feed conversion remained the same (Newport, 1979). The total replacement of skim milk by FPC, markedly reduced the performance and increased the incidence of scouring and mortality (Newport, 1979).

Fish protein hydrolyzate (FPH) derived from fishery processing waste or underutilized species of fish is a relative inexpensive protein source. This trial was designed to evaluate the feeding value of FPH as a supplemental protein source for piglets.

MATERIALS AND METHODS

Twenty percent of total dietary crude protein in two different ration was provided by skim milk and FPH. The FPH used in this trial contained 82-84% CP and 3-5% moisture (Table 1), and was derived from Atlantic Cod (*Gadus morhua*). The ingredient and chemical compositions of diets are presented in table 2. The rations were formulated to be approximately equal in crude protein and metablizable energy.

Thirty pure bred Yorkshire pigs were kept with the sow after birth until they were placed on trial at 3 weeks of age (about 6.7 kg). Six groups of 5 pigs were randomly assigned to two diets with 3 replicates in each. Pigs were alloted in such a way that groups received different diets would have equal sex ratios and similar initial weight. Throughout the experiment, pigs were kept in a 2.44 x 3.05 meter pen equipped with a heater lamp and automatic nipple type waterer. Trials were terminated when pigs weighed 22.5 kg. Individual weights were recorded weekly during the feeding period.

Scouring had been observed in the first two week periods of trial. To prevent this problem, Neo-terramycin (Neo-terramycin, Pfizer Int. Co., contains 20 g oxytetracycline, neomycin sulfate as 14 g neomycin base) was administrated through water in the first week of trial in the third replicates. During the experiment period, pigs were given Neo-terramycin once they were found with diarrhea.

The data for feed conversion and average daily gain at the end of trial were subjected to the Duncan multiple range test for an analysis of variance and difference ($P<.05$) between treatment means (Duncan, 1955).

RESULTS AND DISCUSSION

Feed conversion (FC) and average daily gain (ADG) in FPH group were slightly lower than that in skim milk group (1.97 vs 1.90, 0.82 vs 0.83, respectively), but not statistically different ($P>.05$)(Table 3). Similar results were obtained by Pond et al. (1971)

in which FPC was used as sole protein source in liquid diets for baby pigs. Trials run by Leibholz (1982) indicated that the apparent digestibility of milk protein diets was greater than that of fish protein. This would explain some of the differences in growth between pigs given different diets.

Scouring was more severe in pigs given FPH diets during the initial two periods of the trial. Newport (1979) suggested that the uncoagulated fish protein in the stomach may have increased the flow rate of the digesta, thus caused the greater severity of scouring. The scouring might be one of the reasons contributing to the lower FC and ADG in the FPH group.

The diets were intended to be isonitrogenous based on calculated values for the ingredients. However, analysis of the diets showed that crude protein level was higher in skim milk group by 1.48% (23.3% vs 21.82%). This difference could account in part for the higher growth rate found in skim milk group.

Bauersfeld and Soares (1972) incorporated 15% of menhaden fish soluble in ration to lamb diets at the expense of skim milk and found poor growth. They concluded that if significant quantities of fish protein were to be used in milk replacer rations, protein of higher quality than that present in fish solubles must be used. Seve and Laplace (1975) reported that only one-third of the dietary protein supplied by skim milk could be replaced by FPC for pigs weaned at 12 days of age. However, Pond et al. (1971) observed that FPC was equal to casein and superior to the isolated soybean protein as the sole source of protein in liquid diets for piglets. But in their experiment, the growth of pigs was very low (about 60 g/day from 2-23 days of age). Even though average daily gain was decreased by .005 kg pigs receiving FPH compared to those in the skim milk group, there was no evidence of nonacceptance of FPH by baby pigs in this experiment. The results from this trial indicates that FPH can be used as supplemental protein source to replace skim milk in milk replacers for piglets.

Table 9. Chemical composition of fish protein hydrolysate

	%[a]
Protein	82-84
Oil	5-8
Moisture	3-5
ME (Kcal/kg)	3845

[a]As fed basis

Table 10. Composition of piglet diets

Ingredient	Group: Skim milk	FPH
	%, as DM basis	%, as DM basis
Corn, ground	38.38	47.12
Soybean meal	29.25	27.65
Skim milk	13.44	-
FPH	-	5.77
Tallow	5.46	5.47
Dicalcium phosphate	.66	.82
Limestone	1.09	1.42
Zinc sulfate	0.26	0.26
Vit. premix[a]	0.27	0.27
Mecadox	0.27	0.27
Sucrose	10.92	10.94
Chemical composition		
Dry matter	91.04	90.46
Crude protein	23.30	21.82
Energy (ME, Kcal/kg)	3578	3591
Ether extract	3.56	4.82

[a]Per kg contains: Vitamin A, K, 333,333 USP Units; Vitamin D_3, 444,444 IC Units; Vitamin E, 444 I Units; Vitamin B_{12}, 4 mg; Vitamin K (MSBC) 889 mg; riboflavin, 1778 mg; pantothenic acid, 3,244 mg; niacin, 8,889 mg; choline chloride, 111,111 mg; selenium, 40 mg; and ethoxyquin, 2522 mg.

Table 11. Summary of piglet trial results

Treatment	Average initial wt. (kg)	Average feed conversion	Average daily gain (kg)
Skim milk	6.68[a]	1.90[a]	0.374[a]
FPH	6.71[a]	1.97[a]	0.369[a]

[a]Values in the same column with a common superscript are not different ($P>.05$).

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