EFFECTS OF FISH PROTEIN HYDROLYSATE AND A SELECT MENHADEN FISH MEAL ON STARTER PIG PERFORMANCE

by

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B.S., University of Georgia, 1974

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

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TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

FISH MEAL

AN HISTORICAL PERSPECTIVE

The value of whole fish and fish waste as fertilizer and animal food was known in ancient times. (Borgstrom, 1961; 1962; Cutting, 1956). The use of sun-dried fish as food for domestic animals is mentioned by the Greek historian and philosopher, Herodotus. The Venetian explorer Marco Polo found the same practice common on the coasts of the Arabian Sea. In Siberia fish and fish offal have long been sun-dried before being applied to the land. Europeans in coastal regions have used fish as fertilizer for centuries. Almost every school child in the United States has been taught how Squanto of the Massachusetts tribe taught the Pilgrims to place the "munnawhatteaug" or menhaden, in each hill of Indian corn. Regardless of how the early settlers acquired their knowledge, they began fertilizing with menhaden and other fish.

Until the early part of the nineteenth century, menhaden was still being used, in the United States, primarily as a raw whole fish fertilizer, being plowed directly into the soil. In 1801, Ezra L'Hommedieu, a wealthy landowner on Long Island, published the results of several experiments in which menhaden were applied successfully as soil dressing. L'Hommedieu's claim held promise of increased wealth to farmers living along the seacoast, and a number of small companies soon were organized for the purpose of

supplying menhaden for fertilizers. Thus, the manufacture of fish meal arose from the widespread use of fish as fertilizer.

The special mechanical treatment of fish and fish waste to produce nitrogenous fertilizer and animal feeding meals is a product of the industrialized agriculture of the nineteenth century. In the United States, primarily the fatty fish surplus, not favored for human food, was used for agriculture and later for livestock feeding. In Europe, surplus white fish and offal resulting from the extensive trawl-fishing industries supplied the raw material (Borgstrom, 1961).

It appears menhaden was first processed for oil, in this country, in Rhode Island where during the war of 1812, paint oils became very scarce and fish oil was tried. By 1850, oil was being extracted and used in curing leather, making rope, paints and soaps, and in oil lamps as a cheaper substitute for linseed and whale oils.

The methods first described for the extraction of oil from fatty fish and fish waste on the New England coast were extremely crude, depending on putrefaction to break up the flesh and release the oil. The fish were placed in large casks, salt water was added to cover them, and boards weighted with stones were placed on top of the fish to press out the oil. The fish were then left to rot for several days, after which they were thoroughly stirred with a long stick daily to break up the fish and liberate the oil so that it might come to the surface of the putrid mass. This process was kept up for two to three weeks, the oil being

dipped off daily.

About 1820, processors began boiling the fish in large kettles, stirring frequently and skimming the oil off by hand. The residue was sold to farmers as fertilizer. About 1855, the first crude lever press was constructed in Long Island, New York. By 1860 the first steam works with hydraulic presses was erected at Greenport, New York. Shortly after this screw presses were introduced. The industry expanded considerably during the 1860's and 1870's, processing plants being built all along the Atlantic Coast from Maine to North Carolina.

Oil was the primary product at this time. The residue from the cooking tanks and settling tanks, dried and ground, totalled 64,000 tons in 1880, worth $1,300,000. By this time, the use of whole fish as fertilizer had almost entirely ceased (Cutting, 1956).

During the last quarter of the nineteenth century, the use of dried fish scrap as food for domestic farm animals began to be promoted, although, it is probable such usage was common among farmers along the coasts of New England and Europe. In 1875, feeding trials were conducted in Germany using fish residues in the feeding of sheep. In 1892, the Norwegian government conducted large scale feeding trials to ascertain whether fish waste, after conversion to a dried meal, was a suitable food for farm animals (Cutting, 1956). The success of these experiments and others established fish meal as a feedstuff for animals.

PROCESSING

Fish meal, fish oil and fish solubles are manufactured primarily from pelagic species and/or waste from other processing processes. Purse seines, used to harvest schooling pelagic species such as menhaden, result in large volumes of fish arriving on the catching vessel over a relatively short time period (Wickham, 1971). Vessels planning to land their catch at the processing plant within 24 to 48 hours usually do not attempt to preserve the fish, relying on the short time between harvest and processing to prevent deterioration of the fish. Ships expecting to be at sea longer may mix crushed ice with the fish as it is stored in the hold. Some industrial fisheries use either chilled sea water systems or refrigerated coils in the hold. Expense and, with the chilled sea water system, salt addition, are problems with these procedures (Cohen and Peter, 1962; Connell, 1975; Zaitser, 1965; Hansen et al., 1974; Mjelde and Urdahl, 1974; Eddie, 1974).

Chemicals, such as sodium nitrite, have also been used to prolong life and control bacterial decomposition. Strict processing control is necessary when using sodium nitrite, where it is legal, because the sodium nitrites can react with fish spoilage products to form highly toxic nitrosamines (Windsor and Barlow, 1981)

The addition of about 0.1% formaldehyde has also been used to reduce bacterial decomposition of industrial fish. Formaldehyde will toughen fish that have softened due to deterioration, improving the pressability of the fish during processing.

Formaldehyde must also be used with care, because excessive levels can reduce the nutritional value of the fish (Windsor and Barlow, 1981; Borgstrom, 1961; Borgstrom, 1965(a); Mjelde and Urdahl, 1974).

Several processes have evolved for the manufacture of meal and oil from whole fish or waste products from food fish processing (Borgstrom, 1961; 1962; 1965(a); Gillies, 1975; Knobel et al., 1971; Stansby, 1963; Tannenbaum, 1974; Windsor, 1974). The wet process (Figure 1) is the most widely used, being continuous and capable of handling large quantities of oily fish. the solvent extraction processes also can be used with oily fish but have several disadvantages which have made them little used in the past for production of fish meals. The solvent extraction process represents, however, the basic procedure for the production of the edible fish protein products formerly termed fish flour and now known as fish protein concentrate. Dry reduction processes have also been used for non-oily raw material, and various digestion processes employing both chemicals and enzymes have been used to a lesser extent on similar material.

Menhaden are processed by the wet reduction method in which cooking, pressing, centrifuging of press liquor, and drying of the press cake are the principle operations. Rapid handling of a shipload of fish at the processing plant is essential to prevent loss of the fish. Thus, the processing capacity of most plants is based on the maximum anticipated quantities of fish in a given

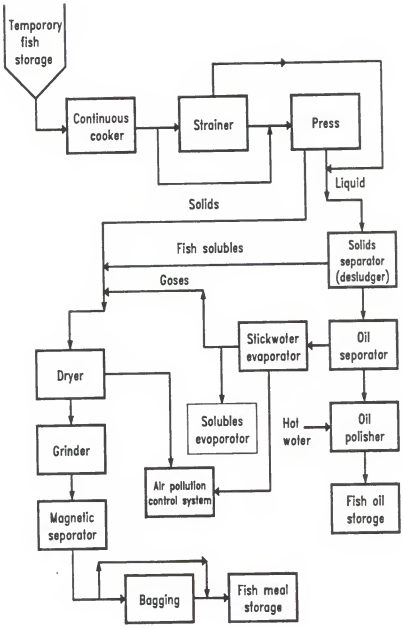

Figure 1. Fish meal and oil processing flow chart.

locality rather than on average landings. Many companies maintain plants in different localities to take advantage of seasonal increases in the availability and abundance of the fish.

Most reduction plants will have facilities for unloading two or more carrier vessels simultaneously. Upon docking, ships are immediately unloaded. Unloading techniques vary, but all are mechanized operations. Chain conveyors, pneumatic, vacuum, and/or liquid pumping systems are used. Typically, the fish are pumped from the carrier vessel by first partially flooding the hold with sea water. The fish and sea water are drawn through openings in the bottom of the hold by pumps and conveyed through a series of pipes and connecting hoses to a dewatering screen. In some plants, the fish are discharged onto a short conveyer belt and automatically weighed. From the weighing belt, the fish are dumped onto a second conveyer belt that carries them directly to a temporary storage bin called a "raw box". In most plants, the fish pass from the dewatering screen into a rotating hopper where they are measured volumetrically and then conveyed to the cooker or raw box. Each segment of the hopper holds 360.5 liters, representing a unit of measure of 1,000 "standard fish". Each 1000 standard fish is estimated to weigh 307 kg. Regardless of the type of weighing equipment used, this unit of measure is used throughout the industry to express the quantity of catch in millions of standard fish (F.A.O. Yearbook of Fishery Statistics, 1983).

COOKING

From storage the fish are conveyed to a continuous cooker where the fish temperature is usually raised to about 95–100 C, although in some processes temperatures as low as 50–60 C are used. Cookers are typically designed to bring the fish to the desired temperature in approximately 20 minutes.

Most of the fish used for meal and oil processing are small, less then 25.4 cm in length, and can be cooked without preliminary chopping. Cooking is necessary to denature the flesh protein and break cell walls so that oil and water can be removed by pressure. Cell wall rupture releases oil and water bound in the cells, a process often releasing 60% or more of the raw fish weight as liquid. Specific cooking conditions must be adjusted to each batch of fish. Fish species, condition, fish temperature when entering the cooker and other variables influence the required cooking conditions. Insufficient cooking fails to adequately release the oil and water. Overcooking produces a soft mass of material, which is difficult, if not impossible, to press and which releases a high proportion of suspended solids into the press liquor. High suspended solids concentrations in the press liquor increase difficulties in later evaporation steps. Thus, close control of cooking is critical to efficient operation of the entire plant.

Direct steam is usually used for heating the mass of fish. In its most common form, the cooker is simply a horizontal cylinder

from 4.5 to as much as 12.2 meters long and from 38 to 76 cm in diameter utilizing a conveyer screw to move the fish. Steam is introduced through manifolds running the length of the cooker. Processing capacity of cookers, pressers and dryers are matched to ensure there is neither an accumulation of cooked fish or press cake when all equipment is operating at its normal capacity. Irregular input or underloading results in inefficient pressing and cooking as well as overheating in the dryer. The raw box permits accumulation of enough raw material to ensure a constant production rate.

Some plants employ an indirect cooker in which the steam is retained in the jacket of the vessel and, usually, also in a special hollow conveyer screw. The indirect cooker has the advantage of reducing the amount of press liquors that need to be centrifuged and later evaporated. It also reduces the loss of solids and increases the yield of scrap and meal. Cost of this type of cooker is higher, and some operators believe that the excess water from condensed cooking steam is necessary to "wash out" the oil during processing.

PRESSING

Some plants pass the cooked fish through a straining operation prior to pressing. The strainer, generally an auger inside a perforated housing, allows some of the free liquid to drain out of the solid mass prior to entering the press. Other

plants gravity feed or convey the cooker output directly to the press. The continuous screw press, usually a double screw system, is in almost universal use. The press is designed to continually increase the pressure applied to the solids as the cooked fish moves along the length of the screw. The increasing pressure squeezes most of the liquid out through the perforated housing. The liquid consists of water, oil, and some small particles. the solid portion remaining after pressing, known as "press cake", will contain about 50-55% moisture.

The objective of the pressing operation is to reduce the oil content from as high as 20% in the raw fish to, ideally, about 3% in the press cake. This would yield a meal with 6% fat, but in fact, meals from oily fish rarely contain less than 8%, average about 10%, and may run as high as 12% to 17% fat. Pressing is a step that is difficult to control and is less than ideally efficient. The pressing efficiency will depend on control of the cooking process and on the quality of the raw material. Soft, deteriorated fish tend to form a viscous semi-solid which will not press well.

Condition of the fish is the main trouble spot. Condition varies from hour to hour, from boat to boat, and with the time the fish have been held in the raw box. Constant supervision and monitoring of both cookers and presses is necessary to ensure a consistent quality product. Temperature indicators on the fish from the cookers and power-input meters for the motors driving the presses help to make this process more science than art.

The liquid removed by the press, known as "press liquor",

typically contains 16% oil, 78% water, and 6% solids. The press cake accounts for about 32%, by weight, of the raw fish entering the plant.

OIL SEPARATION

The hot press liquors are run from the presses to shaker screens to remove course solids, then to a continuous centrifugal separator to remove the fine solids. Solids go back to the presses or may be run directly to the dryers, and the liquid, reheated if necessary, is run to the oil separator. The oil separator is another centrifuge which separates the oil and water. The oil phase is usually quite clean and may be pumped to storage and shipped without further treatment. However, many plants use a second centrifuge to "polish" the oil, removing residual stickwater and solids. This is accomplished by running the hot oil through the centrifuge with about 10% of its volume of clear, very hot water which washes out impurities. Close control of temperature is imperative to provide optimum contaminant removal by the centrifuges.

FISH SOLUBLES

The water fraction leaving the oil separator, known as "stickwater", is a sticky mixture of fish solids (5-6%), water (94%), and a small amount of oil (0.4%). From the centrifuges the

stickwater is usually run to large, temporary holding tanks. Sometimes the hot liquor will be held for 18 to 24 hours, possibly with the addition of enzymes, or until enzyme action and the normal flora of heat-tolerant bacteria cause a partial breakdown of the protein and a consequent reduction in the viscosity of the finished condensed solubles.

The stickwater is then fed to an evaporator, where the solids are concentrated to between 30% and 50%. Stickwater may represent 50% of the original raw fish weight and contain about 20% of the solids in the final meal (Windsor and Barlow, 1981).

In most menhaden plants, stickwater is evaporated to the desired concentrations then acid is added to a pH of 4.0 to 4.5. The acid acts as a preservative and also serves as a protein coagulant, precipitating some of the solids responsible for high viscosity and also freeing oil held in suspension.

Several types of evaporators are used for fish stickwater. Large installations in the United States use large continuous vacuum evaporators almost exclusively. These installations have high capacity and are practically automatic, once control valves are set for a given lot of stickwater. Initial cost is high and scale and corrosion in the steam tubes are common sources of trouble.

Another type of evaporator that has been used with some success is the hot air evaporator. This operates on the same principle as a spray dryer. It is not usually practical to take the stickwater down to 50% solids in one step, so a second stage

evaporator must be included or a temporary storage vat must be provided for a later second run through the same unit.

Stickwater from small reduction operations connected with canneries may be batch-evaporated in steam jacketed kettles. The capacity of this type of equipment is very low compared to vacuum evaporators.

Solubles may be returned to the meal forming a product known as full meal or whole meal. These products are not generally separately identified as marketed. Consequently neither the amount produced in the United States nor the typical proportion of added solids from stickwater in whole meals are figures that can be readily obtained. The amount of stickwater added back is closely correlated with the demand and market price of 50% condensed solubles. When the solubles price is less than half the price for the meal, the larger amount will go into meal and visa versa.

DRYING

The press cake, concentrated stickwater, and solids removed during centrifuging of the oil may be mixed and fed to a dryer. There are two main types of dryer, direct hot air dryers and indirect systems using steam or hot water.

In the direct dryer, very hot air at inlet temperatures as high as 500 C is passed over the material as it is tumbled in a cylindrical drum. Outlet temperatures must be maintained in the

80–100 C range or lower to prevent damage to the meal (Carpenter and Lea, 1962; Madsen et al., 1965). This is the quicker method, but heat damage is possible if the process is not carefully controlled. If properly controlled the meal temperature will not exceed 95 C. Direct dryers are typically designed to dry the wet meal to 9–10% moisture content within 15 to 20 minutes.

Some plants use two direct dryers in series with the stickwater solids added between them. The first dryer can be operated at quite high temperatures to speed drying. Adding the concentrated stickwater solids after partial drying prevents formation of meal clumps which form when meal moisture content become too high. Clumps dry slowly causing increased risk of hot spots leading to lowering of nutritional value or even spontaneous combustion in the stored product. Direct dryers are almost always used in high capacity fish meal plants.

Indirect dryers consist of fixed cylindrical drums with internal rotating scrapers or flights which continuously stir the meal as it is being dried. Heat is provided by high pressure steam passing through the flights or scraper disks running the length of the dryer. Air blown through the drier removes the evaporated moisture.

In this type of dryer, burning the meal is less likely since the meal temperature cannot be raised above that of the steam (168 C @ 100psi). However, longer exposure to temperatures of 120 to 150 C can do as much damage to protein quality as shorter exposure to higher temperatures (Carpenter and Lea, 1962; Madsen

et al., 1965; Mason and Weidner, 1964).

There appears to be little if any nutritional differences between meals from direct and indirect dryers (Wu et al., 1984; Borgstrom, 1962; Ousterhout and Snyder, 1962(b)). The choice of dryers is usually determined by the nature of the raw material, fuel costs and availability, required capacity, available space, and odor reduction problems.

Meal particle size as it leaves the dryer is quite varied. Since most markets demand a uniform particle size, the meal is ground, usually through a hammermill.

CURING

If the meal passes directly from the dryer to a storage bin, it may tend to heat rather than cool. Proper handling of the meal after drying is essential for the preservation of nutritive quality. The highly unsaturated oils in fish meals rapidly oxidize and polymerize in the presence of even limited amounts of oxygen. These reactions develop considerable heat causing damage to protein and even, in extreme cases, fire. Meals differ widely in their reactivity and tendency to heat. Meals that are relatively high in oil, above 10%, and have a moisture content above 8% or 10%, seem more prone to excessive heating.

It is possible to grind, sack and ship some low fat, non-reactive meal as soon as it emerges from the dryer. Other meals can be ground and sacked, but the sacks must be stored in

such a manner as to allow the dispersal of heat. Material which must be handled in bulk form can be stirred, turned, and aerated to cool the product. This curing process is usually continued, either in sack or in bulk, until the reactions slow down enough to allow use of normal methods of handling feedstuffs without danger of fire, caking, or loss of nutrients. The curing process may require from several hours to several days time depending on the composition and processing of the meal. Antioxidants, such as butylated hydroxytoluene (BHT) have been used to prevent overheating and the protein quality and available energy loss that often results (De Groot, 1968; March et al., 1965; Matteson and Ousterhout, 1968; Nielson et al., 1985; Opstredt et al., 1971). BHT reduces the tendency to rapid heating but does not completely prevent oxidation of the meal.

Another factor associated with excessive heating is high temperature of meal entering the storage bin. This may have the most detrimental influence. The critical temperature is about 57 to 60 C; above this, excessive heating occurs, below this point the temperature will hold and gradually fall (Ousterhout and Snyder, 1962b).

Various plants have adopted different practices to avoid excessive heating. Most of these methods involve cooling the meal prior to storage.

Although the bulk of fish meal and oil produced in the world is manufactured by the process described above there are alternative techniques which can be used. Some systems processing

low oil content products such as white fish, crab, or shrimp waste, eliminate the cooker and dry the raw material directly using hot air dryers (Windsor and Barlow, 1981)

DRY RENDERING

Dry rendering is also used to a limited extent. In this process the raw product is dried, usually in steam jacketed rotary vacuum dryers, prior to pressing. Drying must not proceed to below 8% moisture or oil removal during subsequent pressing will be impeded. Pressing is usually accomplished with batch type hydraulic presses operating at 3 to 4 MPa. The resulting press cake may have an oil content as low as 10% and is very compact with a relatively small surface area to volume ratio. The cake is quite resistant to rancidity and thus, has a relatively long storage life (Borgstrom, 1965a).

Dry rendering is not widely used because it is not easily adapted to continuous processing. However, this process can handle essentially any type of raw material (fat, lean, fresh or decomposed) with equal ease. Also, since drying is done at low temperatures under a vacuum, meal nutritional damage is minimized (Borgstrom, 1965a).

HYDROLYZED FISH PRODUCTS

Hydrolyzed fish products are produced by mixing fish,

usually ground or minced, with water and proteolytic enzymes. In fish silage the enzymes naturally present in the fish are used to breakdown the fish flesh. In hydrolyzed products purified enzymes from commercial sources are added to the mixture. The elevated enzyme levels plus close control of pH, temperature and other variables, increase the fish breakdown rate from a matter of several days, as in fish silage production, to a matter of hours.

A general flow process chart for manufacture of fish hydrolysate is shown in Figure 2. The fish are first finely chopped or minced and then placed in a digestion vessel with water and the desired enzymes. In some processes pH adjustment with acid or alkali is used to provide more optimum conditions for digestion and/or to prevent bacterial growth. Upon completion of the reaction, the digestion vessel contents are screened to remove the undigested parts, such as bone, skin, and scales. The liquid is then pasteurized to control bacteria and to inactivate the enzymes. If oily fish are used as raw material, the liquid fraction is passed through a centrifuge to remove as much oil as possible, and to separate the solids into essentially soluble and insoluble fractions. The soluble fraction is then vacuum dried to about 50% moisture and finally spray dried to about 4% moisture (Windsor and Barlow, 1981). Since some oil may be left in the solids after centrifuging, the dried fish hydrolysate may exhibit a fishy odor and/or flavor.

Since the process is relatively new, there are many variations in processing techniques. Processing variables vary

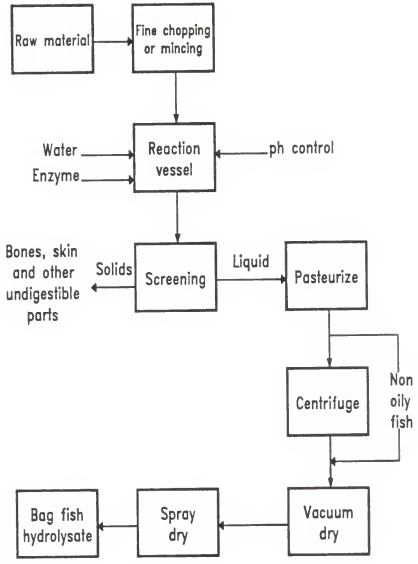

Figure 2. Fish hydrolysate processing flow chart.

widely depending on the fish species processed, enzymes used, bacterial growth controls, and other variables. Reactor vessel temperatures used vary from essentially ambient (25 C) to as high as 70 C. Facin, papain, pancreatin, trypsin, and other commercially available proteolytic enzymes are used.

FISH PROTEIN CONCENTRATE

Fish protein concentration (FPC) is a concentrated protein material originally intended for human consumption. FPC was once thought of as a product that would significantly reduce protein shortage in many areas of the world (Snyder, 1962; Pariser et al., 1978; and Tannenbaum, 1974; Knobel et al., 1971). However, FPC has not become the major protein source originally invisioned. The reasons for this are complex and varied, and certainly beyond the scope of this paper. Marketing problems and government regulatory agencies created an economically unfavorable climate. Consequently, manufacturers have lost interest resulting in cancellation of plans to build processing facilities and closing of some existing plants.

FPC includes a variety of materials produced from fish, including some fish hydrolyzed materials described above. It is typically a dried and ground product which varies in flavor and color depending on the processing technique employed. FPC encompasses products varying from sauces and pastes, traditional in southeast Asia, to flour like products (Amano, 1962; Morrison,

1962; Gillies, 1975; Ernst, 1971).

Stabilizing fish protein requires that the water and oils be largely removed. Chemical extraction processes are used to achieve this separation. The product produced is vary bland and almost tasteless.

Several different processes have been developed (Table A) to produce FPC by chemical extraction. Since the economics of this product generally preclude it from consideration as an animal feedstuff, the processing will not be detailed.

FISH SILAGE

Fish silage is another product which has been utilized to a limited extent in livestock feeding. In fish silage the enzymes naturally present in the fish are used to breakdown the fish flesh (Amano, 1962). As mentioned above, in hydrolyzed products, purified enzymes are added to accomplish the same basic objective. However, the hydrolyzation process allows for closer control than the silage process. Consequently, proteins produced by the hydrolysis process tend to have better functional properties such as dispersibility, water solubility and emulsifibility than those produced by silage methods.

Fish silage is a liquid usually requiring 1 to 5 or more days to produce. Equipment and operating costs are comparatively low and production is relatively simple. Since fish silage has a high moisture content and a low pH, transportation costs are relatively

Table A. Chemical Extraction Processes for Fish Protein Concentrate Production Which Received Significant Research Effort

Development Groups and/or Person	Raw Material	Solvent or Enzymes
Astra	Fresh eviscerated fish	Isopropyl alcohol
Dabsch/UNICEF	Fish meal or fresh hake	Hexane and ethyl alcohol
Fisheries Research Board of Canada	Fresh fish (cod and herring)	Isopropyl alcohol
General Foods Corp.	Fresh fish	Tertiary butyl acohol or isopropyl alcohol
Lever Brothers	Fresh cod	Ethyl alcohol
Morocco	Fish meal made from sardines	Mixture of ethyl alcohol and hexane
NMFS[a]	Fresh hake	Isopropyl alcohol
NMFS	Raw fish	Alkaline protease from Bacillus subtilis
Verrando Bruera	Fish meal from anchovy	Hexane vapor
Vio Bin[a]	Fresh hake	Ethylene dichloride followed by isopropyl alcohol or methyl alcohol
Vogel	Fish meal or fresh fish	Ethyl alcohol

[a]Process approved by the U.S. Federal Food and Drug Administration for sale of FPC in the United States.

high and the product is corrosive. Markets must be developed for fish silage and they must be relatively close because of the high transportation cost (Windsor, 1974).

FACTORS AFFECTING FISH MEAL QUALITY

The annual total world catch of fish is in excess of 70 million metric tons. Of this, about 30% will be used as the raw material for production of fish meals and fish oil (F.A.O. Yearbook of Fishery Statistics, 1983). Fish meal, fish oil, and condensed solubles are all products of the same operation, using as a source of raw material either whole raw fish or waste from fish canneries or other food fish operations. By far, the most important American source of fish for meal, oil, and solubles production is menhaden. Aside from scattered operations where, on a small scale, meal is made form industrial or trash fish, the remaining meal and oil operations in the United States make use of trimmings from fish canning or other food operations (Klima, 1971).

Tuna has become the nations most important food fish and almost 100% of the catch is canned. Thus, the supply of cannery waste is so large that tuna meal accounts for about 10% of the annual fish meal production, second only to menhaden. Tuna meal is primarily a west coast product.

Herring is the main resource on which the meal and oil industries of Iceland, England, and the Northern European

countries are dependent. The only significant herring processing in North America is done in British Columbia, Canada.

Pilchard, Anchovy, Pacific Mackeral, and Jack Mackeral are all caught in the same general area - central and southern California - often by the same boats, canned in the same canneries, and the cannery wastes go the the same drying plants. Thus, the meals made from these species rarely have a separate identity and are, in fact, frequently mixed with tuna meal.

Other fishing vessels working the "banks" off New England land a number of species usually categorized as "ground fish". Included in this grouping are haddock, cod, flounder, ocean perch, whiting, pollock, cask, and hake. Most of this catch is dressed or filleted, and the waste from these operations goes to the meal plants. These are species with a comparatively low oil content, in contrast to those listed above, so that only meal known as "white fish" meal is produced from this source. In recent years there has been considerable competition for this raw material with most of it now going into canned pet food or being ground and frozen for fur animal feeding.

Salmon cannery waste has at times been utilized for meal, though hardly feasible at present. River herring of Chesapeske Bay is also a source as whole fish or as the waste from canned herring or salted or pickled product. The blue crab industry of the central and south Atlantic and Gulf states produces large amounts of waste, a portion of which is dried to yield a low-protein meal. Shrimp waste from canneries on the Gulf coast also

yield a small amount of meal, limited by the fact that most of the catch have heads removed at sea (Borgstrom, 1965a).

Thus, fish meal is a general term for a number of different products that vary in type of raw material and method of production. The proximate composition of fish varies widely from species to species and within species from one individual to another. Individual and species variation is correlated with such factors as season, geographical area, age, sex, size and feed intake (Kukucz, 1962; Makasher et al. 1958; Connell, 1975). Even the proximate composition of the edible flesh varies from one part of the fish to another (Kurtzman et al., 1962). Segments near the head of the fish generally have a higher oil and lower protein content than those near the tail. Fish trimmings usually have a considerably higher oil and ash content and lower protein content than does the edible portion. These factors can result in considerable differences in quality and composition from one product to another (Borgstrom, 1962; Ousterhout and Snyder, 1962b). Thus variation in the nutritive value of industrial fishery products for animal feeding have been attributed to differences in the raw material, and to changes in nutrient content and availability during the processing and handling of the product. Much of the research on fish meal have been attempts to determine amount of and reasons for variation.

From the moment fish is taken from the water a series of deteriorative changes occur which eventually will render the fish unmarketable (Borgstrom, 1961; Makasher, 1958; Chichester and

Graham, 1973; Mjelde and Urdahl, 1974). These changes occur relatively rapidly, such that fish is probably the most perishable of all flesh foods.

These changes occur as either the result of microbial action or chemical change. Proteins and lipids are subject to various chemical reactions affecting nutrient quality. However, changes resulting from microbial action are the most extensive.

Post mortem, muscle metabolism reactions become irreversible resulting in accumulation of lactic acid and decline in pH. Acidity of pH 5.8 to 6.2 are observed at peak rigor. The minimum pH attained varies somewhat with the species of fish, being a function of the initial glycogen content, the buffer capacity of components of the fish tissue, and the rate of the various post mortem reactions which result not only in accumulation of lactic acid but also its subsequent oxidation and disappearance. The lowering of the pH will decrease the rate of bacterial multiplication and thus prolong the keeping quality of the fish to some extent (Makasher, et al., 1958).

Another immediate post mortem change important only in certain cases occurs where fish have been feeding on certain types of food which have activated the digestive enzymes to a high degree. Even under normal circumstances the fish will contain active proteolytic enzymes, particularly in the gut (Ousterhout and Snyder, 1962b; Dollar and Blackwood, 1962). The integrity of the gastrointestinal tract will suffer during handling post mortem resulting in the whole fish becoming substate for its

digestive system. When this occurs, extensive proteolysis of the tissue adjacent to the digestive tract occurs such that in extreme cases all of the flesh adjacent to the backbone, and sometimes extending deep into the muscle is completely liquified. If this liquified protein; a mixture of amino acids, peptides and soluble protein, is lost during transfer of the fish, the meal produced may have a significantly lower protein content. These and other post mortem changes brought about by various enzymatic reactions result in an increase in free amino acid concentration (Mjelde an dUrdahl, 1974; Connell, 1975; Makasher et al., 1958). The free amino groups are available for reactions with reducing sugars or other products of oxidation of lipids, which may render the amino acids unavailable. This process can be inhibited by low temperature and low moisture (Borgstrom, 1961; Makasher, 1958).

Fish muscle normally contains high amounts of free amino acids, varying from 1 to 5 grams per 100 grams of protein. The pattern of free amino acids as well as the amount of free amino acids is characteristic for different species. Some free amino acids function in osmoregulation resulting in quantitative differences in individual amino acids in fish from different zones of salt concentration. Protein bound amino acids show a much more uniform pattern, however, protein of fish muscles can be electrophoretically separated into different components characteristics for given species (Connell, 1975). In spite of these differences, the mean value for individual amino acids expressed as a percentage of total protein displays a remarkable similarity

between species (Borgstrom, 1962; Bramstedt, 1962; Stansby, 1962).

The pattern of free amino acids changes during the earliest stages of rigor mortis due to the activity of endogenous proteolytic and peptidase enzymes. These enzymes are major factors in protein degradation and spoilage, especially in the initial stages before bacterial invasion takes place (Siebert, 1962; Dollar and Blackwood, 1962; Mjelde and Urdahl, 1974; Connell, 1975; Makasher et al., 1958).

In general the bacteria found on living fish are predominately psychrophilic, sea water loving (though not necessarily absolutely halophilic), aerobic, and attack proteinaceous tissue more actively than carbohydrates. Fish and shellfish living in water polluted from terrigenous sources may carry significant numbers of bacteria normally associated with land animals, though even under these conditions such bacteria never occupy a preponderant position of the total associated bacterial flora. However, the occurrence of such types is important from the sanitary and public health standpoint (Chichester and Graham, 1975).

On the death of the fish the humoral defenses against bacterial invasion cease to operate and mechanical barriers such as skin and membranes gradually lose their impermeability. In addition, mechanical damage of the fish, resulting in breaks in the skin barrier and crushing of tissues will facillitate primary penetration of the tissues by bacteria just as the expressible fluid with its protein an amino acid content will serve as an

excellent medium for growth and reproduction of invading bacteria, hastening spoilage. The parallel liberation of structure bound enzymes will further act to degrade protein and facilitate spoilage (Borgstrom, 1961; Borgstrom, 1962; Makasher et al., 1958; Dollar and Blackwood, 1962). As a result of these and other changes post mortem, the balance between bacteria and host animal is upset, and qualitative and quantitative changes in these bacterial populations soon become evident. Changes in the bacterial flora are of enormous importance since, together with associated endogenous biochemical and physical changes in the fish tissue, they lead to the process of spoilage and ultimate decay and dissolution of the cadaver.

For a short period after death, corresponding rather closely to the onset, duration, and resolution of rigor mortis, there is little change in the numbers of bacteria present. This period is followed by a typical sigmoidal growth curve. Bacteria numbers gradually increase then pass through a period of exponential growth before leveling off, bacteria numbers then remaining essentially constant. Despite the slowing of growth at this point, this is the period of maximum spoilage activity, terminating only when the fish has reached putridity (Makasher et al., 1958; Chichester and Graham, 1975; Mjelde and Urdahl, 1974).

This classical growth sequence occurs in all fish and shellfish samples held under chilling conditions (i.e. greater than 0 C, less the 10 C). Special treatments, such as pasteurization, antibiotic ices, nitrite, etc. may affect the timing of events by

lengthening the growth curve, but such measures will not stop the spoilage process entirely (Hansen et al., 1974; Mjelde and Urdahl, 1974; Stansby, 1965; Borgstrom, 1961).

The primary activity of the spoilage bacteria occurs in the surface layers of the fish, and the total effect is largely due to secondary diffusion of bacterial enzymes and products into the deep tissues. On a quantitative basis, the major chemical changes in fish resulting from microbial spoilage are the production of nitrogenous bases, particularly trimethylamine and ammonia, and to a lesser extent of volatile fatty acids. The trimethylamine is principally derived from the reduction of trimethylamine oxide, which is present in nearly all marine species and absent in fresh water species (Connell, 1975; Mrochkov, 1958; Stansby, 1963; Borgstrom, 1962).

While neither storage on ice or deep freezing will inhibit enzyme activity totally, use of these procedures for fresh caught fish will effectively inhibit enzyme activity and bacterial growth significantly slowing spoilage. Dirty ice, reused ice, or ice stored for long periods in fish rooms will harbor large numbers of psychrophilic fish spoilage bacteria and, therefore, the use of such ice can bring about a shortening of the acceleration phase of bacterial growth leading to more rapid spoilage. A similar effect will be observed by exposure of fish to improperly sanitized equipment (Stansby, 1963; Hansen et al., 1974; Eddie and Hopper, 1974; Zaitser, 1965; Mjelde and Urdahl, 1974; Makasher et al.,1958; Ivanova, 1958).

Of all the physical and chemical factors which affect bacterial growth, temperature is probably the most important. Any laxity in temperature control (e.g. through use of insufficient ice or poor brine cooling) will result in accelerated bacterial growth and more rapid spoilage (Borgstrom, 1961).

Theoretically, the fish scrap leaving the presses is sterile. However, conveyers and various other equipment will rapidly accumulate large population of fish bacteria if proper sanitary practices are not observed. Transposition of these bacteria to the scrap will reinitiate the spoilage process (Chichester and Graham, 1973; Mjelde and Urdahl, 1974).

One of the purposes of processing is to interfere with the activities of the spoilage bacteria. Partial inhibition is most commonly achieved by maintaining the temperature of the fish close to O C by the use of ice or refrigerated brine. Chemical additions such as nitrites, benzoates, etc. also bring about partial inhibition of the sensitive portion of the bacterical flora, but yield the same results as chilling – a delay in the rate of increase of the spoilage bacteria populations. These substances are generally used in association with chilling, the combined inhibitory effect being additive. These measures are only effective if applied immediately after the death of the fish. Once the spoilage flora has entered the period of exponential growth such measures are of little use (Borgstrom, 1961; Hansen et al., 1974; Mjelde and Urdahl, 1974).

In spite of the tendency of rapid spoilage and the potential

for microbial growth, fish products are very rarely implicated as causes of food poisoning. This may be due to the natural floras (in contradistinction, for instance, to fowl in which Salmonella occur naturally); the normal practice of holding fish products at low temperatures; and the controlling influence of the normal and putrefactive spoilage flora on stored fish. Food poisoning organisms will not, in general, grow significantly at low temperatures (i.e. below 10 C), but the normal flora, since it is primarily psychrophilic in nature, will grow quite actively. In situations where the temperature is high enough to permit growth of dangerous organisms, the natural flora will, in most cases, grow very much faster so that the potential pathogens are swamped and eventually die out. In precooked products, such as fish meal, the extremely heat-sensitive natural flora is largely wiped out and may, under poor sanitary conditions, be replaced by an essentially mesophilic contaminant flora which may contain significant numbers of bacteria from human sources (Chichester and Graham, 1973).

FISH MEAL AS A PROTEIN SOURCE IN DIETS FOR SWINE

"It has been clearly demonstrated that no single figure can be devised to represent the value of a protein, because proteins are not entities, but a collection of various amino acids combined in various ways and present in various concentrations." Thus, Grau and Carroll (1958) suggested that protein quality is a

function of amino acid balance, with respect to amino acid requirements, and amino acid availability. This was not a new concept however, prior to the 1950's, technology required for appraising availability and requirements as well as accurate analytical procedures was not sufficiently advanced to allow for evaluation of proteins in these terms.

Since this time the available knowledge of nutrient requirements has increased tremendously. Efficiency of analytical techniques as well as chemical estimates of amino acid availabilities have also benefitted from technological advancement in the last three decades. As a result of these advancements, and others, the amount of information generated has been overwhelming. Consequently, in an effort to facilitate digestion, enormous data banks have been constructed to more accurately estimate the requirement as well as the influence environmental conditions and genetics may have on nutritional requirements of specific species of animals. Large date banks have also been constructed to allow more precise and accurate evaluation of individual feed ingredients and their nutritional worth. Today most feed manufacturers rely on data banks for informative description of nutrient content of individual feed ingredients. These data banks are very powerful exerting a great deal of influence in the feed industry. From an economic standpoint, such data banks can mean the difference between a profit and a loss. Since decisions of such tremendous impact must be made based on these data banks, they must contain accurate information. Thus,

data banks require frequent editing with obsolete data being replaced by current and more reliable data.

Causes of obsolescence include: 1) new cultivars, 2) crop-year effects, 3) changes in ingredient manufacturing processes, 4) improved analytical procedures and 5) more accurate estimates of nutrient worth or availability. Thus, the purpose of this review is to update the data base on utilizing protein derived from fish as a dietary protein source for pigs.

Sibbald and Wolymetz (1984) evaluated samples of menhaden fish meal from 5 different manufacturers. Significant differences between meals among the 5 manufacturers were observed for nitrogen, crude fiber, ash, calcium, and phosphorous. However, for crude fiber, ash, and phosphorous there were no significant differences among 4 of the manufacturers. There were no significant differences among manufacturers for ether extract, gross energy, or estimated metabolizable energy.

Despite the differences observed, the authors concluded these differences may reflect a high analytical precision and that such differences may be of little practical importance for diet formulation because the level of fish meal inclusion is usually low.

The literature records a number of experiments from various countries in which the nutritive value of fish meals have been evaluated with pigs. An outstanding feature of these studies is that fish meal has generally exerted a substantial growth promoting effect, increased intake, and/or improved feed

efficiency. Results have been rather striking, particularly in some of the earlier studies in which it proved necessary to use higher levels of plant proteins to match the performance yielded by a fish meal diet. This was especially true when the all vegetable diet contained groundnut meal (Woodman and Evans, 1951; Carpenter et al., 1956) and also when soybean meal was used instead of groundnut meal, though the difference was less (Evans, 1952). In contrast Kirsch (1959) found no difference when a fish meal was compared to soybean on an isonitrogenous basis.

The conditions and diets utilized in these experiments differ greatly. Therefore, the effect should accordingly not be expected to be uniform. In these studies, it is probable that fish meal exerted its influence by improving the amino acid balance of the diet and possibly by fortification with minerals and various vitamins. For example, the results observed supplementing groundnut meal with fish meal can easily be explained in terms of improved amino acid balance. Groundnut meal has been shown to be low in methionine and lysine (Ranjhan et al, 1964; Thomas and Kornegay, 1972; Orak et al., 1975; Orak and Bowland, 1975). Fish meal, on the other hand, has been shown to be a good source of available methionine and lysine (Hewitt and Ford, 1985). Thus these two protein sources are complimentary and when used together result in an improved amino acid balance of the entire diet and corresponding improvements in performance.

With the increased understanding of nutritional requirements, basal diets of more recent studies are improved in vitamin and

mineral content to the point that little response would be expected from these contributions by the fish meal.

The positive effect of fish meal on weight gain, feed efficiency and feed intake in growing broilers is well documented (Fraps, 1928; Fraps, 1944; Fraps, 1946; Hill, 1959, Hill and Renner, 1957; Matteson et al., 1955; Potter et al., 1962; Cooper, 1974; Perschel et al., 1976(a); 1976(b); Alenier and Combes, 1981; Touchburn et al., 1974; Wu et al., 1984). Similar effects have been described by various researchers for growing turkeys (Potter and Shelton, 1976; Pierson et al., 1976; Potter et al., 1977; Potter and Shelton, 1978; Potter et al., 1980; Potter et al., 1981; Salmon, 1982). The results obtained by these researchers in growing broilers and turkeys has been remarkably consistent in showing increased weight gains, feed intake, and/or improved feed efficiency.

Pond et al. (1971) conducted a study to determine the acceptability of fish protein concentration as a protein source in a liquid diet for the baby pig weaned at 2 days of age. Performance was compared between diets utilizing casein, fish protein concentrate, or isolated soybean protein at isonitrogenous levels, as the protein sources. Fish protein concentrate was judged equal to casein, in promoting growth and total serum protein concentration, after 21 days of feeding. Isolated soybean protein was inferior to fish protein concentrate or casein for both criteria.

Pettigrew et al. (1972) conducted a similar study feeding

2-day old weaned pigs 20% protein diets in which 100% of the protein was from fish protein concentrate, 100% from milk or 50% from fish protein concentrate and 50% from milk. Although the diet containing 100% milk protein numerically gained the fastest with the 50%/50% diet yielding gains numerically intermediate, treatment means were not statistically significant. Therefore, it was concluded that fish protein concentrate is equal to milk protein in promoting growth in the 2 to 21 day old weaned pig.

Newport (1979) conducted a study in which half or total replacement of dried skim milk by fish protein concentrate and dried whey was compared with a diet containing dried skim milk as the only source of protein for the 2-day old weaned pig. Total replacement of dried skim milk by fish protein concentrate and dried whey severely reduced performance. Replacement of half the dried skim milk significantly improved growth rate and numerically, but not significantly, improved feed efficiency.

Newport and Keal (1983) reported results similar to Newport (1979) which indicated fish protein concentrate was markedly inferior to milk protein when used as the major protein source in diets for the 2-day old weaned pig.

The apparent confusion in results may be due to drastic differences in observed daily gains between trials. Pond et al. (1971) reported average daily gains varying from 50 grams to 70 grams. Pettigrew et al. (1972) reported average daily gains of 33 grams to 55 grams. In contrast, daily gains recorded by Newport (1979) and Newport and Keal (1983) were 130 grams to 249 grams

and 96 to 315 grams respectively. Both Newport (1979) and Newport and Keal (1983) observed when dried skim milk was totally replaced by fish protein concentrate performance was very poor and was associated with a higher incidence of scouring and mortality.

Johnson et al. (1962) conducted a series of experiments with rats comparing FPC, egg protein, skim milk, casein and beef protein using the protein efficiency ratio technique (PER). These workers concluded FPC, when used to supply 10% of the dietary protein, was equal to milk protein. In conclusion, fish protein concentrate can probably be utilized in a diet for the 2-day old weaned pig in which a minimum of 50% of the protein is supplied by milk sources.

Leibholz (1982) fed dry pelleted diets to 7 day old weaned pigs to assess the utilization of casein, fish meal (unidentified origin) and soybean proteins (supplied as either soybean meal or isolated soybean protein). Diets were formulated containing 35.8% fish meal, 50.5% soybean meal, 23.7% isolated soybean protein, or 25.3% casein. Results indicated the apparent DM digestibilities of soybean (SBM 87%; ISP 92%) and fish protein (91%) were less than those of milk protein diets (95%). Average daily gains were also lower for the soybean and fish protein diets compared with casein.

Rodriquez and Young (1980) fed four diets in which herring meal made up 0, 20, 40, and 60% of the dietary protein. Average daily gains decreased numerically (223, 207, 206, 184 g/day) with increasing proportions of herring meal in diet, however,

differences were not significant. Feed efficiency was also similar for all diets.

One review (Gulbrandsen, 1984) cites work done by Okai et al. (1976) as evidence supporting claims of increased weight gains of weaned pigs when herring meal is included in the diet. In fact, a significant increase in feed intake and average daily gain was associated with increasing herring meal content (0, 5.4 and 11%) of the diet. However, as herring meal was increased as a proportion of the diet, milk products (dried skim milk and dried whey) were also increased as a percentage of the diet (0, 10 and 35%). Substitutions were made at the expense of soybean meal and grain sources (wheat, barley and oat groat). Diets containing the highest levels of herring meal and milk products contained no grain. In addition, dextrose, sucrose, and corn starch were included in the most complex diet, but were omitted from the other two. Despite the fact that herring meal contributed up to 33% of the dietary protein in the most complex diet, no definite conclusion can be drawn regarding the effect of fish meal on postweaning performance of the 3 week old pig due to the large number of confounding dietary variables.

A study by de Moura and Zocoler (1983) compared soybean protein and a protein supplement made up of equal parts of white fish meal and dried milk. In comparison with the fish meal plus milk diet, the soybean diets resulted in daily gains at least 22% less from three to five weeks of age and 11% less from three to eight weeks of age. The authors concluded the better response of

pigs on the fish meal and milk diet was due to the suitability of this protein fraction to the digestive capacity of the three week old weaned pig. They also suggested this advantage diminishes after 40 days of age.

Pike (1978) conducted a study to examine performance of 3 week old weaned pigs fed a high nutrient density diet (DE=4230 Kcal dry matter; CP=20.9%; lysine 1.0%) or a conventional diet (DE=3608 Kcal/kg DM; CP=18.8%; lysine 0.75) with or without 5% fish meal. On the conventional diet growth rate and feed efficiency were significantly improved (278 g/day vs 372 g/day; 3.69 vs 3.25) when fish meal was included. On the high nutrient density diets fish meal increased growth rate and improved feed efficiency numerically (396 g/day vs 406 g/day; 2.52 vs 2.44), but not significantly. The growth rate on both high nutrient density diets was not different from growth rates returned by the conventional diet plus 5% fish meal.

Gjefsen et al. (1980) contrasted two types of herring meal, one with 78.5% protein and 11.5% fat, with dried skim milk as a protein source for the 3 week old weaned pig. The herring meals were combined with dried whey in a ratio of 4:1 on a protein basis to make up the dietary protein source. When fed in combination with dried whey both fish meals gave equal performance to dried skim milk.

In summary these investigations indicated that fish meal in combination with dried milk products will generally improve performance of early weaned pigs when compared to diets

containing only vegetable protein sources.

Laksesvela (1961) fed diets containing 8 levels of herring meal (0, 3, 4, 5, 6, 8, 10 and 12%) to pigs beginning at 20 kg. The inclusion rate of herring meal was reduced as the pigs grew according to the schedule below:

Period	Weight Range (kg)	% of initial inclusion rate
1	20–30	100
2	30–50	75
3	50–65	50
4	65–80	25
5	80–90	0

Increasing levels of herring meal produced improved average daily gains and feed efficiency. Levels of herring meal beyond 8% initial inclusion resulted in no further improvement. Average daily gain increased 12% and feed efficiency was improved 8% compared with pigs on all vegetable control diets. The animals were slaughtered at 90 kg live weight and loin cuts were evaluated by taste panels. The authors reported significant reductions in palatability for loins from animals on diets with initial fish meal inclusion rates in excess of 8%.

Aas et al. (1984) reported inclusion of herring meal at the level of 2% in grower finisher diets containing 10 or 20% rapeseed meal improved performance to levels equal to or greater than all soybean meal diets. Meat from pigs receiving the herring meal diets were not evaulated for palatability. However, at a 2% inclusion rate no problem was anticipated.

Combs (1962) reviewed the literature and concluded for swine and turkeys during the finishing period the level of fish meal in the diet should not exceed 2-5% to avoid the possibility of off-flavors in the meat.

A review by Braude (1962) suggested swine could be fed 7% fish meal up to 54.5 kg and 3% through to market weight.

The amount of fish meal included in growing pig diets in Sweden prior to 1985 was restricted to a level which contributes no more than 0.5% of the crude fat to the complete feed. However, new regulations introduced January 1, 1985 restrict the amount of fish meal to a level corresponding to a maximum of 0.2% fish oil in the final feed. If spot tests on carcasses indicate this level has been exceeded, penalties of up to 100 Swedish kroner per animal will be imposed on all pigs from the producer responsible.

The effect of fish meal on the reproductive performance of animals is not clear. In turkeys a number of experiments (Couch and Atkinson, 1953; Feldman et al., 1957; Whiteside et al., 1960; Potter and Leighton 1971; Touchburn et al., 1972; Waldroup et al., 1972; and Touchburn et al., 1974) have consistently demonstrated improved hatchability on diets containing fish meal

compared to all-vegetable diets, and similar effects have been found in Japanese quail (Latshaw and Jensen, 1970; Touchburn, 1974). The response to fish meal addition has not been so clear cut with breeding hens. Only small to negligible positive effects on reproductive performance was reported by Pepper et al. (1961), Menge (1967) March et al. (1967), and Cooper and Hughes (1974). Opstredt and Gjefsey (1975), reported including fish meal in the diet had no effect on live weight gain, age at sexual maturity, or on rate of mortality and breeds broiler hens. However, they reported a significant increase in egg production, number of settable eggs, improved feed efficiency, an increase in percentage of fertile eggs and hatchability of fertile eggs. Fish meal inclusion in the diet had no effect on live weight of viable chicks and caused a significant decrease in average egg weight. The total amount of feed required per viable chick produced on 0, 2, and 4% fish meal diets was 671 g, 579 g and 507 g, respectively.

Reasons for different results obtained in these studies are not immediately obvious. Since the effect of fish meal seems to be associated with improving fertility and/or decreasing early embryonic death, the possibility exists that differences between treatments in some studies (March et al., 1967; Cooper and Hughes, 1974) may have been obscured by the practice of evaluating treatment effects on hatchability of "fertile eggs". The possibility of breed differences also exists. A broiler breed were used by Opstredt and Gjedsen (1975), whereas, light breeds was used in the other studies.

The effect of fish meal on the reproductive performance of sows also is not clear. Palmer et al., (1970) reported inclusion of menhaden fish meal in a corn-soybean meal diet at a level of 6.67% for two consecutive reproductive cycles in two consecutive generations, significantly increased the average daily gain of gilts and sows during gestation and resulted in a significant increase of 0.9 pigs born live per litter. Baker et al. (1974) reported addition of menhaden fish meal at 3% of the diet did not enhance reproduction performance contrasted with observed performance on the basal corn-soybean meal diet. Tibbetts et al. (1981) also found no differences in reproductive performance of sows between feeding a 6% fish silage and a corn-soybean meal diet. Baker et al. (1974) suggested that since the basal diet used by Palmer et al. (1970) did not contain either supplemental Vitamin E or selenium the positive response in reproduction performance observed may have been due to vitamin E and/or selenium contributed by fish meal addition to the basal diet. This conclusion was supported by work done by Grifo and Moxon (1973) showing an increase in selenium levels in sows blood, sows milk, and suckling pigs blood corresponding to increasing levels of fish meal in the sow diet. However, since the authors did not indicate these increases in selenium content were statistically significant it must be assumed they were not. In addition, work done by Charez (1979a) and Charez (1979b) indicates plasma selenium levels are not necessarily indicative of the selenium nutritional status of the pigs. They suggest glutathione peroxidase activity should be used

as an index of nutritional selenium status in the pig.

Fish meal has been shown to contain comparatively high amounts of selenium (Grifo and Moxon, 1973; Cantor et al., 1975; Gabrielsen and Opstredt, 1980; Cantor and Tarino, 1982). Although some of these same researchers have estimated the availability of selenium in fish meal to be between 30% and 50% for chicks (Cantor et al., 1975; Gabrielsen and Opstredt, 1980) and turkeys (Cantor and Tarino, 1982).

Thus the role selenium played, if any, in the fish meal response observed by Palmer et al. (1970) is open to question. Fish meal contributes a wide range of vitamins and nutrients in addition to amino acids and fat, any one or combination of which may have contributed to the improved performance observed by Palmer et al. (1970). In conclusion, fish meal must be considered an acceptable protein source for reproducing animals but any added effect on reproductive performance in comparison to other protein sources, should not be expected in sows and gilts.

EFFECTS OF FISH PROTEIN HYDROLYSATE AND DRIED WHEY IN STARTER PIG DIETS

Summary

Four experiments were conducted to evaluate Fish Protein Hydrolysate (FPH) as a protein source in starter diets for pigs. A total of 552 3 week old weaned pigs averaging 5.95 kg were used in three growth trials and one digestion study. All three growth trials were designed to determine the effect of FPH with and without dried whey (DW) on starter pig performance. The digestion study was designed to determine the effect of FPH with and without dried whey on nutrient digestibility.

There were no FPH X DW interactions in any of the trials, therefore, results are discussed in terms of main effects of FPH and DW. On each of the three growth trials, addition of 3% FPH improved average daily gain (ADG) ranging from increases of 8% (trial 1, P=0.10) to 17% (trial 3, P=0.02) over the corn-soybean basal diet. Feed efficiency and average daily feed intake (ADFI) were not affected by the addition of FPH. Dried whey additions with or without FPH resulted in no improvement over performance observed with the 3% FPH diet in either Trial 1 or Trial 3. In Trial 4, 20% dried whey added to a corn-soybean meal diet improved performance for all criteria measured to a level equal to that with 3% FPH alone. Growth responses to the addition of dried whey were inconsistent from trial to trial, possibly the result of

heat damage to the dried whey. Therefore, conclusions regarding dried whey additions with or without FPH may be confounded with dried whey quality.

The digestibility study indicated no apparent difference for any of the criteria measured between the FPH diets and the basal diet. However, the addition of dried whey resulted in improved dry matter digestibility and energy digestibility over the basal diet. There were no differences observed for crude protein digestibility or percent nitrogen retention.

Introduction

Fish protein hydrolysate is the dried enzymatic digest of clean, undecomposed, whole fish or fish cuttings subjected to a hydrolytic enzyme process. The product is free of bones, scales, and undigested solids as well as most of the oil. The hydrolytic process is carefully controlled such that proteins are not split to free amino acids, but are processed to small polypeptide chains. Theoretically, the addition of FPH to starter diets would provide partially predigested proteins and give the young animal a "head start" on the digestive process. It is assumed that protein hydrolytically broken down by enzymes into short chains of amino acids has increased protein availability and subsequent digestibility. As can be seen from the analysis (Table 1), FPH contains 84% protein and appears to be an excellent source of lysine, tryptophan, and threonine.

There is currently renewed interest in replacing soybean meal with other protein sources for pigs weaned at 3 weeks of age.

Composition and complexity of the diet is frequently discussed in relation to postweaning pig performance. Several studies done recently in Canada and the United States have indicated that pigs weaned at 3 weeks of age performed best when fed complex diets; however, the economics of feeding a complex diet must be evaluated on an individual basis. This study was conducted to evaluate the effect of FPH, as part of a semi-complex and a complex diet in a starter diet for the early weaned pig.

Experimental Procedures

Pigs averaging 22 days of age were moved from a total confinement, environmentally controlled, farrowing facility into one room of an environmentally controlled nursery. Pigs were housed in pens (1.22 m x 1.52 m) with woven wire floors over a Y-flush gutter, with one nipple waterer and one four-hole, self-feeder per pen. Temperature and air flow were adjusted to maintain optimum comfort for the pigs.

All four trials utilized the same basal corn-soybean meal diet (Table 2), containing 4% added fat, .3 ppm selenium, and 250 ppm copper sulfate, representing a "simple" diet. This diet was formulated to contain 21% crude protein, .9% calcium, .7% phosphorus, and 1.26% lysine. All diets were formulated on an isolysine basis.

In all three growth trials, pigs were blocked by weight and randomly assigned to pens, each pen being randomly assigned to a treatment. Each growth trial lasted 5 weeks. Criteria measured were averaged daily gain (ADG), average daily feed intake

(ADFI), and feed efficiency expressed as feed/gain (F/G). Pigs were fed as libitum. Feeders were checked twice daily and all feed additions recorded. Individual pigs weights were collected at the end of each 7-day period.

Trial 1. This trial was designed to determine the optimum feeding level of FPH with and without whey. In this trial, 180 3-week old weanling pigs weighing an average of 5.89 kg were used in 2 x 3 factorial design with two levels of dried whey (0 and 20%) and three levels of FPH (0, 3, and 6%). Animal health was excellent throughout the trial period.

Trial 2. Trial 2 was a digestion study, conducted concurrently with Trial 1. It was designed to evaluate the effect of FPH with and without dried whey on nutrient digestibility. Dry matter digestibility (DMD), crude protein digestibility (CPD), digestible energy (DE), as well as percent nitrogen retention (%NRET) were evaluated. A cross-over design was utilized with diets formulated to contain two levels of dried whey (0 and 20%) and two levels of FPH (0 and 6%). Twelve pigs, with an average initial weight 6.21 kg were used with two 5-day collection periods. Each collection period was preceeded by a 5-day adaptation period.

Trial 3. This trial was designed to determine if part of the dried whey in a 20% dried whey starter diet could be replaced by FPH. Trial 3 was a growth trial using 120 3-week old weanling pigs weighing an average of 5.89 kg in a 3 x 2 factorial design with three levels of dried whey (0, 10 and 20%) and two levels of

FPH (0 and 3%). Animal health was excellent throughout the trial period.

Trial 4. Trial 4 was designed to determine if the effect of FPH noted at the end of 5 weeks could be achieved by feeding FPH for only the first 2 weeks. Trial 4 used 240 3-week old weanling pigs, weighing an average of 5.98 kg. Diets were formulated to contain two levels of whey (0 and 20%) and two levels of FPH (0 and 3%).

Treatments are shown below:

Treatment	Diet (wk 1-2)	Diet (wk 3-5)
1	Basal	Basal
2	Basal + 3% FPH	Basal
3	Basal + 3% FPH	Basal + 3% FPH
4	Basal + 20% Dried Whey	Basal
5	Basal + 3% FPH + 20% Dried Whey	Basal
6	Basal + 3% FPH + 20% Dried Whey	Basal + 3% FPH + 20%

Results and Discussion

There were no FPH x DW interactions observed in any of the four trials conducted. Therefore, results are discussed in terms of main effects of FPH and DW.

Trial 1. Addition of FPH to starter diets did not affect ADG

by week 2 of the trial. However, by the end of week 5, a quadratic ($P<.08$) improvement in ADG was observed with the 3% FPH diet showing an improvement over the 6% FPH and the basal diet (Table 3 and 4). Adding FPH at either 3 or 6% of the diet had no significant effect on ADFI and F/G. There was, however, a numerical improvement in ADFI of 4% and F/G of 3% corresponding to the increase in ADG with the 3% FPH addition (Table 4). Addition of 20% dried whey had no effect on ADG, F/G, or ADFI (Table 5). This is in contrast to numerous studies done at Kansas State and other universities, demonstrating the beneficial effects of dried whey addition to starter pig diets. The beneficial effects of dried whey on pig performance have been shown to be highly correlated with dried whey quality (Mahan, 1984). The lack of a dried whey response in this study may have been due to a poor quality whey in these diets.

Trial 2. Addition of 20% dried whey resulted in improved ($P<.01$) DMD and DE utilization (Table 6). However, the addition of 20% dried whey had no effect on CPD or % NRET. The increase in DE from dried whey addition may be due to the lactose portion of the dried whey improving the DMD, since lactose is the major energy source in dried whey. FPH had no effect on any of the digestibility criteria measured.

Trial 3. Addition of 3% FPH resulted in no improvement in ADG by week 2 (Table 7). Again, as demonstrated in Trial 1, by the fifth week the 3% FPH diet without dried whey improved ($P=.02$) ADG 17% over the basal diet. Additions of dried whey to

the diet with or without FPH resulted in a slight numerical improvement in ADG compared to the control diet. Dried whey additions yielded ADG responses numerically intermediate between the basal diet and the 3% FPH diet without dried whey. Addition of either dried whey or FPH to a corn-soybean meal diet resulted in no significant improvement in ADFI or F/G. Although, addition of 3% FPH tended to increase ADFI.

Trial 4. Similar to results in Trails 1 and 3, the addition of 3% FPH without dried whey did not improve ADG by the end of the first 2 weeks after weaning (Table 8). However, by the end of week 5, adding 3% FPH again resulted in a 10% improvement in ADG (P=.06). The addition of 20% dried whey resulted in ADG equal to the response from 3% FPH. Additions of 3% FPH together with 20% dried whey improve ADG by 22% over the basal diet and 11% over diets containing either 3% FPH or 20% dried whey. Results indicate no additional advantage in ADG to feeding the 20% dried whey plus 3% FPH diet beyond the second week postweaning. Based on these results, feeding a diet with 3% FPH for 2 weeks after weaning appeared to give equal performance to feeding FPH during the entire 5-week trial. Since the 3% FPH diet is more expensive than the control diet, feeding FPH for only the first 2 weeks compared to 5 weeks after weaning would reduce the cost of gain.

Feed efficiency was improved similarly by all treatments compared to the basal diet. Adding dried whey resulted in most of the improvement in F/G by the end of the second week. Adding 3%

FPH resulted in a slight improvement in F/G by the end of the fifth week. However, F/G was not different from FPH or dried whey additions ($P>.05$).

Feed intake was increased ($P<.05$) by the addition of 20% dried whey with 3% FPH by the end of the second week. This advantage was then maintained through the fifth week. Results indicate no advantage in starter pig performance from feeding the 20% dried whey plus 3% FPH diet beyond the second week postweaning. Addition of 3% FPH again displayed a tendency to increase ADFI.

In each growth trial, addition of 3% FPH resulted in ADG. In each case, the increase in ADG was accompanied by a non-significant increase in ADFI and a tendency to improve F/G. Fish protein sources have been shown to increase ADFI and/or improve F/G (Laksesvela, 1961; Pike, 1978; Galbrandsen, 1984) by other researchers. Since the digestion trial did not evaluate the effect of 3% FPH on digestibility, this cannot be ruled out as a contributing factor in promoting the observed response in ADG. Based on the results and observations presented here, it is postulated 3% FPH exerts its influence on ADG through the combined effects on ADFI and F/G. Economic consideration may preclude use of FPH as a major protein source in swine diets. Results of this study indicate FPH will optimize ADG at relatively low levels, although, no detrimental effects were noted at higher levels.

Table 1. Fish Protein Hydrolysate - Analysis

Item	Content
Dry matter	96.0%
Crude protein	84.0%
Crude fat	5.0%
Metabolizable energy	3851 kcal/kg
Calcium	0.15%
Total phosphorus	0.60%
Lysine	6.10%
Tryptophan	0.75%
Threonine	3.50%

Table 2. Basal Diet Composition[a].

Ingredient	Percent
Corn	55.11
Soybean meal (44% CP)	36.74
Fat (soybean oil)	4.00
L-Lysine HCL (feed grade 98%)	0.10
Selenium	0.15
Copper sulfate	0.10
Dicalcium phosphate	1.70
Limestone	1.00
Trace mineral premix[b]	0.10
Vitamin premix[c]	0.25
Salt	0.50
Antibiotic[d]	0.25

[a]Calculated to contain: protein 21%, calcium .9%, phosphorus .7%, lysine 1.26%

[b]added to provide per ton of complete feed: 4.12 million IU vitamin A; .65 million IU vitamin D; 125 g vitamin E; 2.5 g vitamin K; 226.5 g choline; 26.5 g niacin; 12.5 g d-pantothenic acid; 25 mg vitamin B_{12}; 3.3 g riboflavin.

[c]added to provide: 106 ppm zinc; 106 ppm iron; 29 ppm manganese; 10.5 ppm copper; 0.19 ppm iodine; 0.07 ppm selenium.

[d]110 g chlortetracycline; 110 sulphamethazine; 55 g penicillin.

Table 3. The Effect of Fish Protein Hydrolysate With and Without Whey in Starter Diets for Pigs (Trial 1).[a]

Item		FPH%:	0	3	6	0	3	6	SE
		Dried whey %:	0	0	0	20	20	20	
ADG wk 0–2	g		154	165	158	160	179	166	17
ADG wk 0–5[b]	g		359	372	346	348	395	371	17
ADFI wk 0–2	g		251	252	233	226	258	244	18
ADFI wk 0–5	g		567	558	577	526	585	562	24
F/G wk 0–2			1.64	1.54	1.49	1.44	1.47	1.51	.093
F/G wk 0–5			1.58	1.51	1.51	1.52	1.48	1.53	.034

[a]6 pigs/pen; 5 pens/treatment.
[b]Quadratic response from the addition of FPH, P=.08.

Table 4. The Effect of Fish Protein Hydrolysate in Starter Diets for Pigs - Main Effects Means (Trial 1)[a].

Item	FPH%	0	3	6	SE
ADG wk 0-2	g	157	172	162	12
ADG wk 0-5[b]	g	354	383	358	12
ADFI wk 0-2	g	239	255	238	13
ADFI wk 0-5	g	548	572	544	17
F/G wk 0-2		1.54	1.51	1.51	.066
F/G wk 0-5		1.55	1.50	1.52	.024

[a]6 pigs/pen; 5 pens/treatment
[b]Quadratic response P=.08

Table 5. The Effect of Dried Whey in Starter Diets for Pigs - Main Effects Means (Trial 1).[a]

Item	Dried Whey %:	0	20	SE
ADG	wk 0–2	159	169	9
ADG	wk 0–5	359	371	10
ADFI	wk 0–2	245	243	10
ADFI	wk 0–5	550	559	14
F/G	wk 0–2	1.56	1.47	.054
F/G	wk 0–5	1.53	1.51	.020

[a]6 pigs/pen; 5 pens/treatment

Table 6. The Effect of FPH with and without Whey on Digestibility in Starter Diets for Pigs (Trial 2).

Item		FPH%:	0	6	0	6
		Dried whey %:	0	0	20	20
DMD[a]	%		82.2	82.4	85.0	86.0
CPD	%		82.4	82.5	83.6	83.8
DE[a]	%		82.7	82.1	84.4	85.4
%NRET			60.2	64.3	63.9	65.7

[a]Effect of dried whey addition, $P<.01$.

Table 7. The Effect of FPH with and without Whey in Starter Diets for Pigs (Trial 3).

Item	FPH%:	0	3	0	3	0	3	
	Dried whey %:	0	0	10	10	20	20	SE
ADG wk 0–2	g	228	259	241	221	241	244	19
ADG[2] wk 0–5	g	392[a]	458[b]	413[ab]	420[ab]	422[ab]	419[ab]	18
ADFI wk 0–2	g	283	310	291	282	293	306	16
ADFI wk 0–5	g	599	656	600	602	613	609	24
F/G wk 0–2		1.27	1.20	1.20	1.28	1.23	1.28	.072
F/G wk 0–5		1.55	1.43	1.45	1.43	1.45	1.46	.037

[a]4 pigs/pen; 5 pens/treatment.
[b]Effect of dietary treatment, P=.02.

Table 8. The Effect of Duration on Feeding FPH with and without Dried Whey in Starter Diets for Pigs (Trial 4)[a].

Item	FPH %: / Dried whey %:	Period[b] 1 2	1 2	1 2	1 2	1 2	1 2	SE
		0 0	3 0	3 3	0 0	3 0	3 3	
		0 0	0 0	0 0	20 0	20 0	20 20	
ADG[c] wk 0–2 g		131[a]	141[ab]	154[ab]	178[bc]	187[c]	205[c]	15
ADG[c] wk 0–5 g		334[a]	365[b]	373[b]	384[bc]	383[bc]	407[c]	12
ADFI[d] wk 0–2 g		209[a]	200[a]	211[a]	235[ab]	262[b]	272[b]	17
ADFI[e] wk 0–5 g		519[a]	523[a]	535[a]	575[ab]	584[b]	614[b]	23
F/G[d] wk 0–2 g		1.61[a]	1.46[ab]	1.44[ab]	1.32[b]	1.42[ab]	1.36[b]	.076
F/G[d] wk 0–5 g		1.55[a]	1.44[b]	1.44[b]	1.50[ab]	1.52[ab]	1.50[ab]	.038

[a] 8 pigs/pen; 5 pens/treatment.
[b] Period: 1=wk 0 through wk 2; 2=wk 3 through wk 5.
[c] Effect of dietary treatment, P<.06.
[d] Effect of dietary treatment, P<.05.
[e] Effect of dietary treatment, P<.08.

EFFECT OF A SELECT MENHADEN FISH MEAL IN STARTER DIETS FOR PIGS

Summary

A growth study was conducted to evaluate the effect of a select menhaden fish meal (SMFM) as a protein source in starter diets for pigs. A total of 150, 3-week old weaned pigs averaging 4.8 kg were utilized. Diets were formulated by replacing soy protein with protein from SMFM. The replacement of soy protein with SMFM elicited a quadratic response (P=.01) in average daily gain (ADG) and average daily feed intake (ADFI) by the end of week 5. Inclusion of SMFM at 8% yielded the maximum observed ADG, whereas ADFI was maximized with the 12% SMFM diet. Addition of SMFM did not affect feed efficiency (F/G). These results suggest that SMFM may have potential as a protein source in starter diets for the early weaned pig.

Introduction

Fish meal has been promoted as a feed ingredient for farm animals in this country for more than 100 years. Many studies have been conducted demonstrating beneficial results from including fish meal in the diets of several domestic animals. In the scientific literature, one can find numerous studies with swine from various countries in which fish meal has generally exerted a substantial growth promoting effect as well as improving F/G and ADFI. In contrast, however, other workers have found no differences in performance of pigs fed either fish meal or plant protein sources.

Inconsistencies in response resulting from fish meal

supplementation are indicative of the variation that exists in the quality of different fish meals. Fish meal is actually a general term for a number of different products that vary in type of raw material and method of production. The proximate composition of fish varies widely from species to species and is correlated with such factors as season, geographical area, as well as, fish age, sex, size and feed intake. Different methods of fish processing would include oil removal, heat treatment, and drying. Some fish meals may be objectionable because they are not fresh or contain excessive fat or moisture.

Fish meal is a protein source; consequently, the ultimate value of fish meal in a diet will depend on its quality and its effect on the total amino acid balance of the diet. A better evaluation of fish meal quality should be based on source and chemical analysis to determine protein level, quality, and amino acid availability. With this objective in mind, an effort is being made by fish meal manufacturers to identify high quality fish meal through chemical analysis and ultimately market a selected product of consistent quality. It was one such product that was evaluated in this study.

In considering fish meal for use in practical diets, it is of extreme importance to recognize that values derived from standard tables giving compositions of feed ingredients refer to averages, and that the range associated with these averages may be considerable. The analysis of SMFM used in this study is given in Table 1.

Table 1. Select Menhaden Fish Meal Analysis

Item	Amount
Protein	61.6%
Oil	11.9%
Lysine	4.7%
Methionine	1.9%
Methionine + cystine	2.5%
Calcium	5.4%
Phosphorus	3.2%
Salt	1.0%
Digestible energy	4118 kcal/kg

Experimental Procedure

One hundred fifty pigs averaging 3 weeks of age and 4.8 kg were moved from a total confinement, environmentally controlled, farrowing facility into one room of an environmentally controlled nursery. Pigs were not allowed access to creep feed during the lactation period. Pigs were housed in pens (1.2 m x 1.5 m) with woven wire floors over a Y-flush gutter, with one nipple waterer and one four-hole self-feeder per pen. Temperature and air flow were adjusted to maintain optimum comfort for the pigs.

Table 2. Composition of Experimental Diets Containing Select Menhaden Fish Meal

Ingredients	Percent SMFM					
	0	4	8	12	16	20
Corn	33.05	36.11	40.92	44.95	49.05	52.30
Soybean meal (44% CP)	30.50	25.00	19.00	13.00	6.00	
SMFM		4.00	8.00	12.00	16.00	20.00
Dried whey	25.00	25.00	25.00	25.00	25.00	25.00
Fat (Soybean Oil)	6.70	5.80	4.00	3.00	2.30	1.50
L-Lysine HCL (Feed grade 98%)	0.20	0.25	0.15	0.10	0.10	0.05
DL methionine	0.10	0.07	0.03			
Selenium	0.15	0.15	0.15	0.15	0.15	0.15
Copper sulfate	0.10	0.10	0.10	0.10	0.10	0.10
Dicalcium phosphate	3.00	2.30	1.70	0.80	0.30	0.30
Limestone	0.40	0.50	0.30	0.30	0.40	
Trace mineral premix[a]	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix[b]	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.20	0.12	0.05			
Antibiotic[c]	0.25	0.25	0.25	0.25	0.25	0.25

[a] added to provide: 106 ppm zinc; 106 ppm iron; 29 ppm manganese; 10.5 ppm copper; 0.19 ppm iodine; 0.07 ppm selenium.

[b] added to provide per ton of complete feed: 4.12 million IU vitamin A; 65 million IU vitamin D; 125 g vitamin E; 2.5 g vitamin K; 226.5 choline; 26.5 g niacin; 12.5 g d-pantothenic acid; 25 mg vitamin B_{12}; 3.3 g riboflavin.

[c] 110 chlortetracycline; 110 sulphamethazine; 55 g penicillin

Experimental diet compositions are given in Table 2. These diets were formulated to contain 19.50% crude protein, 3688 kcal/kg digestible energy, 1.40% lysine, 0.72% methionine +

cystine, 1.30% calcium, 1.00% phosphorus. Treatments were formulated by substituting fish meal protein for soy protein. Levels of select menhaden fish meal inclusion were 0, 4, 8, 12, 16, and 20%. It should be noted that 20% SMFM totally replaced soybean meal in the diet. All treatments were formulated to contain the same levels of crude protein, digestible energy, lysine, methionine + cystine, calcium, phosphorus, and salt.

Pigs were blocked by weight and randomly assigned to pens, with 5 pigs/pen and 6 pens/treatment. Each pen was randomly assigned to a treatment. The study was conducted for 5 weeks. Criteria measured were ADG, ADFI and F/G. Pigs were fed ad libitum. Feeders were checked twice daily. Individual pig weights were collected at the end of each 7-day period. Animal health was excellent throughout the trial period.

Results and Discussion

Results are given in Table 3. Addition of a select menhaden fish meal did not affect ADG by the end of week 2 of the study. However, by the end of week 5, a quadratic (P=.01) effect in ADG was observed with the 8% SMFM diet yielding maximum ADG of 418 g/day. This represents an 11.5% increase in ADG over pigs on the basal diet, which were gaining 373 g/day.

The 20% SMFM diet, in which all the soybean meal was replaced by SMFM, yielded ADG not different from the basal diet, which contained no SMFM and utilized soybean meal as the main protein component. This suggests that complete removal of soybean meal from the diet of the young pig did not improve pig

performance.

It has been suggested (Newby et al., 1985) feeding very high quality diets to the 3 week-old weaned pig may contribute significantly to enteric disease immediately postweaning. This condition is said to be associated with an aberrant immune response to dietary antigens i.e. soy protein. These researchers further suggest, adequate feeding of soy protein prior to weaning will completely abrogate any malabsorption, crypt hyperplasia or diarrhoea post weaning. Furthermore, abrupt changes in the diet imposed on pigs at weaning will trigger on aberrant immune response leading to postweaning diarrhoea and the economic loss generally associated with this condition. The results of this study do not support the above hypothesis, however, such a conclusion is confounded by the inclusion of an antibiotic in the basal diet.

Examining ADFI, again no differences between treatments were observed by the end of week 2. However, by the end of week 5, a quadratic effect (P=.01) was observed in ADFI. Maximum ADFI of 595 g/day was observed with the 12% SMFM diet. This represents approximately 17% improvement in ADFI over the basal diet response of 504 g/day.

Inclusion of SMFM at all levels yielded no differences in F/G at the end of 2 weeks. By the end of week 5, pigs on the basal diet were returning a very acceptable F/G of 1.34. The inclusion of SMFM at all levels resulted in F/G similar to the basal diet response by the end of week 5.

Results of this study corresponding quite closely to those of

Kjeldsen et al. (1981) in which a similar select fish meal was fed to pigs weaned at 4 weeks of age. Fish meal substitution levels were the same as this study (0, 4, 8, 12, 16, and 20%). Quadratic effects were noted for both ADG and ADFI. Both ADG and ADFI were maximized by the 12% fish meal diet. Feed efficiency was unaffected by fish meal addition.

Feed efficiency response observed by Kjeldsen et al. (1981) as well as the present study demonstrate no differences in the pigs ability to convert either soy protein or fish protein to gain. Since fish meal had no effect on F/G in either study, it is postulated the increase in ADG is primarily a result of increased ADFI.

Based on the results of this study, fish meal can be used as the major protein source in formulating starter rations for pigs, although, economic considerations may limit its practical application.

Table 3. Effect of SMFM Additions to Starter Diets for Pigs

Item	% SMFM						
	0	4	8	12	16	20	SE
ADG, g wk 0–2	204	209	236	209	236	204	12
ADG, g wk 0–5[a]	373	404	418	409	404	400	10
ADFI, g wk 0–2	236	236	236	236	254	213	10
ADFI, g wk 0–5[a]	504	529	586	595	545	527	16
F/G wk 0–2	1.14	1.16	1.00	1.13	1.08	1.07	.032
F/G wk 0–5	1.34	1.31	1.40	1.44	1.36	1.32	.062

[a]Effect of SMFM quadratic (P=.01)

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EFFECTS OF FISH PROTEIN HYDROLYSATE AND A SELECT MENHADEN FISH MEAL ON STARTER PIG PERFORMANCE

by

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B.S., University of Georgia, 1974

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

Fish meal processing methods and factors affecting quality are discussed. A review of literature pertaining to fish meal composition and its influence on digestibility as well as growth, feed intake and feed efficiency in swine is included. Two studies were conducted evaluating the effects of fish protein hydrolysate and a select menhaden fish meal in starter diets for pigs.

In the first study four experiments were conducted to evaluate Fish Protein Hydrolysate (FPH) as a protein source in starter diets for pigs. A total of 552 weaned pigs were used in three growth trials and one digestion study. All three growth trials were designed to determine the effect of FPH with and without dried whey on starter pig performance. The digestion study was designed to determine the effect of FPH with and without dried whey on nutrient digestibility.

Adding 3% FPH to starter pig diets resulted in an improvement (8–17%) in average daily gain (ADG) over a corn–soybean meal basal diet. Feed efficiency and average daily feed intake (ADFI) were not affected by the addition of FPH. Dried whey additions with or without FPH resulted in no improvement over performance observed with the 3% FPH diet in either Trial 1 or Trial 3. In Trial 4, 20% dried whey added to a corn–soybean meal diet improved performance for all criteria measured to a level equal to that with 3% FPH alone. Growth responses to the addition of dried whey were inconsistent from trial to trial, possibly because whey utilization may have been impaired by heat damage to the dried whey. Therefore,

conclusions regarding dried whey additions with or without FPH may be confounded with dried whey quality.

The digestibility study indicated no apparent difference for any of the criteria measured between the FPH diets and the basal diet. However, the addition of dried whey resulted in improved dry matter digestibility and digestible energy over the basal diet. There were no differences observed for crude protein digestibility or percent nitrogen retention.

The second study was conducted to evaluate the effect of a select menhaden fish meal (SMFM) as a protein in source in starter diets for pigs. A total of 150, 3-week old weaned pigs were utilized. Diets were formulated by replacing soy protein with protein from SMFM. The replacement of soy protein with SMFM elicited a quadratic response in average daily gain (ADG) and average daily feed intake (ADFI) by the end of week 5. Inclusion of SMFM at 8% yielded the maximum observed ADG, whereas ADFI was maximized with the 12% SMFM diet. Addition of SMFM did not affect feed conversion.

The results of these studies indicate use of fish meal products as protein sources in starter diets for pigs will generally improve growth performance when compared to a standard corn-soybean meal starter ration.