

Nutritional Value of Fish Oils as Animal Feed

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INTRODUCTION

Fish oils have been incorporated in animal feeds for many years. They are used because of their growth-promoting effects, their cheap source of energy, and their vitamin A and D content. They have been used because of observations about their overall values and only now are we beginning to learn the possible reasons for their nutritional properties. Recently concepts have been advanced about interrelationships of fatty acids and about balanced fatty acids. As we learn more about these interrelationships we may find that the very broad spectrum of fatty acids found in fish oils (see Chapter 1) is more beneficial than has been realized.

Although concepts of lipid nutrition are changing, much valuable research has been done in the past on fish oils as well as other animal and vegetable fats and oils. This work has pinpointed problems and limitations relative to incorporating fats and oils in diets and fortunately has shown the necessary preventative measures, which insures optimum utilization. These problems and the necessary preventive measures will be discussed later in this chapter.

GROWTH

Fish oils support growth of animals at least equal to that of any other source of fat in the diet. This often has been considered surprising by those who equate the presence of the classical essential fatty acids as necessary for growth. For a long time only linoleic, linolenic, and arachidonic acids were thought to have essential fatty acid activity. As techniques to study lipids improved, other members of the linoleic and linolenic families of fatty acids were both shown to be active, particularly in promoting growth.

Thus, although the amounts of linoleic and linolenic acids are low in fish oils, the amount of fatty acids in the linolenic acid family is high. The reason for the growth-promoting activity of fish oils can be seen in Table 45A by comparing the amounts of the linoleic + linolenic acid series in fish oils with the amount of linoleic acid in tallow, which is often used to supply the fat in animal diets.

The growth-promoting activity of the linolenic acid series from fish oils was demonstrated in nutritional studies by Privett *et al.* (1959). They fed EFA deficient rats supplements of C₁₆, C₁₈, C₂₀, and C₂₂ fatty esters frac-

TABLE 45A

AMOUNTS OF LINOLEIC AND LINOLENIC FAMILY FATTY ACIDS IN MARINE AND ANIMAL OILS AND FATS

Fat or Oil	Linoleic Series, %	Linolenic Series, %	Total, %
Menhaden	2	31	33
Herring	2	17	19
Tuna	5	33	38
Tallow	2	<1	2-3

tionated from tuna oil and compared results with a supplement of ethyl linoleate. The supplements did not cure dermal symptoms but all but the C₁₆ fraction had growth-promoting activity equivalent to the ethyl linoleate.

These data on linolenic-series acids were supported in nutritional studies by Privett *et al.* (1960) who also showed that menhaden, herring, and tuna oils fed to EFA deficient rats at a ten per cent level in the diet not only stimulated growth but also cured dermal symptoms.

Our knowledge of the interaction of fatty acids of different series when fed together in mixtures is still incomplete. Some evidence would indicate a depression of linoleic acid metabolism when large quantities of members of the linolenic acid family are present (see Chapter 22).

More research is needed to clarify these interactions. Coefficients of digestibility of marine oils reflect their feeding and their growth-promoting values. Analyses by different laboratories on different animals report high values for fish oils (Artman 1964; Deuel 1954; Leoschke 1959; Reder 1942).

Thomasson (1955, 1956A, 1956B) studied the rate of intestinal absorption of oils and fats and found that, although a correlation apparently exists between rate of absorption and growth action, some oils do not conform to this and that longevity of the animals may be as important as either absorption or growth action in evaluation of the oils. Absorption of whale oil was similar to lard but less than butterfat, corn oil, soybean oil, or coconut oil. Steenbock *et al.* (1936) compared rate of absorption of fats from the alimentary canal of rats and reported that halibut-liver oil, cod-liver oil, and butter oil were absorbed more rapidly than lard, corn oil, or partially hydrogenated fats.

The digestion and absorption of fish oils are confirmed by the often-made observation that addition of fish oils in the diet is reflected in the composition of the fats in different animals (Ault *et al.* 1960; Century *et al.* 1961; Edwards and Marion 1963; Feigenbaum and Fisher 1959).

Metabolizable energy and feed efficiency of fish oils are high. Renner and Hill (1958) reported that the metabolizable energy value of menha-

den oil for chicks is 3700 calories per pound. Tallow has a value of 2900 calories per pound. Artman (1964) studied fats as energy sources for chicks and found that menhaden oil supported good growth and had good feed efficiency, high metabolizable energy value, and digestibility when the oil was fed at levels less than 12%. March *et al.* (1965A, 1965B) found that the metabolizable energy of herring oil was 1502 calories/lb. of diet when the oil was added at a level of ten per cent of the diet.

FAT SOLUBLE VITAMINS

Vitamins A and D

Many species of fish store large amounts of vitamins A and D in their livers. The actual amounts of vitamins A and D vary tremendously, not only among different species (Bills *et al.* 1935) but also among different fish within the species. This variation within species depends on age, sex, and size. After vitamin A was synthesized and produced commercially, production of the liver oils for vitamins A and D became a minor industry in North America. Market still exists, however, because the liver oils are still incorporated into animal feeds. Other oils, although they are not fed for this purpose, also contribute vitamins A and D to the diet. Menhaden oil, for example, contains 200–500 units of vitamin A per gram and 50–100 units of vitamin D per gram.

Both body oils and liver oils from fish have been fed to furnish vitamins A and D to poultry, swine, cattle, and fur-bearing animals. Much of the nutritional research in the 20's and 30's on fish oils was aimed at determining the value of fish oils for this purpose. A voluminous literature exists on this topic, but no attempt will be made here to include it because excellent reviews have already been written on the use of fish oils as sources of these vitamins, on the requirements of various animals, and on the metabolism and nutritional value of vitamins A and D (Bills 1954; Cruickshank 1962; Deuel 1951, 1954, 1957; Goodwin 1954; Lambertsen and Braekkan 1956; Moore 1953; 1957; Olson 1964).

Vitamin E

Fish oils contain varying amounts of vitamin E. Einset *et al.* (1957), reported the following amounts in commercial fish oils: herring 140, menhaden 70, and tuna 160 micrograms per gram of oil. The variation of the vitamin E content may be a partial explanation of differences in stability of various oils.

Adequate vitamin E is critical in diets because of the diseases that result from its deficiency and because an increase in polyunsaturated acids increases the requirement of some animals for vitamin E. More research is

needed to resolve the current controversy about the role of vitamin E, its relation to metabolism of unsaturated fatty acids, and whether other antioxidants will serve the same purpose, but many practical aspects of the problem have been established.

Many species of animals develop nutritional muscular dystrophy from a vitamin E deficiency. Species differences are apparent and requirements for vitamin E vary. The progressive muscular dystrophy in man is not thought to be related to a vitamin E deficiency. Mattill and Golumbic (1942) found that muscular dystrophy induced by cod-liver oil was the same as nutritional muscular dystrophy produced in animals by lack of vitamin A. Mattill (1938, 1940) previously had questioned the direct toxic action of cod-liver oil and had shown that vitamin E was oxidized in the presence of unsaturated fatty acids undergoing oxidation.

Vitamin E deficiency in chicks results in encephalomalacia. Hammond (1941) related outbreaks of encephalomalacia in chicks with a factor in cod-liver oil that destroyed, inactivated, or prevented utilization of vitamin E and resulted in exudative diathesis in chicks. Dam (1943, 1944) found that when no fat was added to the diet the former was never produced and the latter rarely. When linseed oil, lard, or five per cent cod-liver oil or its fatty acids was added, both conditions were produced. Dam and Granados (1945) reported that the causative factor(s) was concentrated in the fraction with an iodine value of 283. The importance of supplying adequate vitamin E has been demonstrated many times (Blaxter *et al.* 1953A, 1953B, 1962; Brown 1953; Bunnell *et al.* 1954, 1956; Cormier 1948; Dam *et al.* 1958, 1964; Griffiths 1961; Jensen *et al.* 1955, 1956; Maplesden and Loosli 1960; Moore *et al.* 1959, 1961; Scott 1951, 1953; Singsen *et al.* 1954A, 1954B, 1955A, 1955B).

OXIDATION OF FISH OILS

Most nutritional problems attributed to fish oils are related to their oxidation. Oxidation can occur in the diet itself and cause destruction of vitamins and possibly loss of amino acids. It may also occur *in vivo* particularly in cases of vitamin E deficiency as discussed above. Fish oils or fish oil fatty acids are not of themselves toxic, but oils with peroxide values over 100 may cause toxic symptoms. Values this high are never found in fish, seldom in fish meal, and only very rarely in fish oils.

Kaneda *et al.* (1955) fed ethyl esters of the fatty acids from fish oils with an iodine value of 370 to mice and rats. Every precaution was taken to avoid oxidation of esters. Growth and feed consumption were both good. This led the authors to believe that the toxicity attributed to fish oils was due to autoxidation products. They then let the highly unsaturated material autoxidize at room temperature and found a high level of tox-

icity in the fraction that would not form urea complexes. Common *et al.* (1957) also found toxicity in this fraction. After extensive experiments, Kaneda *et al.* (1955) concluded that peroxides were the most toxic of the autoxidation products. The lethal dose of peroxides was above 278 mgm. total peroxide per kg. of fat. These and other workers have shown that high levels of peroxides are damaging to animals and that the level of peroxide rather than the source of oil, whether fish, other animal, or vegetable, is the cause of toxicity. Matsuo (1954A, 1954B) also related toxicity of fish oils to their peroxide content. Ethyl esters with a P.V. of 240 mgm. per cent were toxic to rats. These esters then were heated for 120 hours at 212°F, had a P.V. of 30 mgm. per cent, and were no longer toxic. Matsuo (1960, 1962) also reported that oxidized ethyl esters from fish oils were toxic when absorbed through the skin. Groot and Kleinobbink (1953) fed rats a diet containing ten per cent oxidized cod-liver oil. The rats grew normally when the peroxide value was less than 24 or when the oil had been heated in a vacuum. Decreased growth occurred when the peroxide value was greater than 54. Rasheed *et al.* (1963) reported that fresh menhaden oil fed to rats at the ten per cent level supported growth equal to the control diet containing lard. When the oil was oxidized to P.V. 125 and above, toxic symptoms began to appear. They also added the antioxidants ethoxyquin or vitamin E to the diet along with a menhaden oil with a P.V. of 60. They found that even under these conditions the antioxidant afforded considerable protection to the rat. Carpenter *et al.* (1963) fed herring oil with a P.V. of 142 to chicks at a level of six per cent in a diet designed to prevent vitamin deficiencies and found no depression in weight gain or in feed consumption.

Polymerized Oils

Nutritive value of polymerized oils depends upon the method of preparation (Common *et al.* 1957; Kaneda *et al.* 1955; Raulin and Petit 1962; Witting *et al.* 1957). In general, oils treated at high temperatures for a long period will be a poor feed additive. Fish oils polymerized under mild conditions have been reported to have good nutritive value (Kaneda 1955; Nicolaysen and Pihl 1953). When polymerized oils have had poor nutritive value, the factors involved include poor digestibility (Lassen *et al.* 1949; Raulin *et al.* 1962) and poor acceptance by the animal (Oldfield and Anglemier 1957). Although the polymerized fish oils cause poor growth in animals, they apparently are not actually toxic. Matsuo (1960) incriminated cyclic monomers formed during heat polymerization as causes of decreased nutritive value.

FISH OILS IN ANIMAL DIETS

All animals can utilize fish oils for energy and for growth when the oils are included in a balanced diet adequately fortified with vitamins. Another requirement is that the amount of oil fed to animals that are being grown for food use must be limited to avoid development of undesirable flavors. This requirement applies only to the extracted oil and not to oil in fishery products such as fish flesh or fish meal.

Fish meals are used in feed formulations primarily for poultry but also sometimes for cattle, swine, and pets. The high nutritional value of fish meal for these animals of itself indicates that the 5-8% lipid in the fish meal is satisfactory. This conclusion has been supported by experimental studies. Scott (1951) extracted oil from sardine meal and from menhaden meal and fed them to turkeys at levels of 1 and 2%. The turkeys did not develop enlarged hock disorders that they did when 1 and 2% fish-liver oils were fed under the same conditions. March *et al.* (1962) extracted the lipid fraction from herring and studied its nutritive value for the chick. The extracted oil gave no evidence of toxicity when fed at the ten per cent level providing the diet was adequately fortified with vitamins.

When meals cause a poor growth rate, experimental evidence indicates that the problem is not so much oxidized oils as the results of reactions between the fat oxidation products or free radicals and the protein with part of the amino acids becoming unavailable to the animal. Carpenter *et al.* (1963) oxidized herring meal, extracted the lipid, and found that the oxidized lipids were not toxic to chicks. They repeated the studies on an anchovy meal that was known to have poor nutritional value under practical commercial conditions. The extracted lipid was not toxic to chicks. The experimental conditions in both series were chosen to preclude any effect from vitamin deficiencies. The residual meal did depress the growth of the chick, supporting the above thesis that the oxidizing lipids render some of the amino acids of the protein unavailable.

Poultry

Fish oils in poultry are efficiently utilized by the birds and permit growth. Much work has been done to determine the optimum amount of the oils and the conditions under which they can be incorporated in the diet. The oils must be fresh and have low peroxide values, and oxidation in the diets must be prevented. The principal limitations are the effects on flavor and stability of the carcass and the increased requirement of the chicks for vitamin E.

Artman (1964) obtained good growth and feed efficiency when menhaden oil was fed at 4 $\frac{1}{2}$ % and 9% in the diet but 15% oil gave poor results. The breaking point in his test appeared to be about 12%. Both menha-

den and soybean oil mixed with tallow (1:1) increased utilization of the tallow. The ability of commercial fish oils to promote growth and feed efficiency in poultry have been reported by other workers (Dansky 1962; Edwards *et al.* 1961, 1962, 1963; March and Biely 1955).

Effects on Poultry Products.—The amount of fish oils that can be incorporated in poultry diets is determined by their effect on poultry products. Laying hens can be fed 2–6% fish oil because of the beneficial effect on egg production and hatchability. Broilers should be fed no more than one per cent fish oil because larger amounts will cause off-flavors and odors in the animal carcasses.

Eggs.—Fish oils fed to laying hens have a beneficial effect on egg production. Biely *et al.* (1954) fed six per cent herring oil to layers for 11 months. The birds consumed eight per cent less feed and egg production was the same. Thus the amount of feed required to produce a dozen eggs was decreased. Edson (1932) reported after a three-year study that two per cent cod-liver oil increased egg production and hatchability. Increased egg production was also reported by Erikson and Insko (1934) and by Holmes *et al.* (1937) when 1–2% body oil was fed and by Kudo (1947) when oil from the waste portion of fish was fed. Antioxidants have been recommended in diets containing two per cent fish oil to prevent destruction of carotenoids and formation of pale yolks.

“Fishy” flavors are sometimes found in eggs but these can not be related to fish oils. These off-flavors and odors often occur when fishery products have not been included in the diet. In addition, excessive amounts of both fish oils and fish meals have often been fed without causing any “fishy” flavors or odors in the eggs. Vendell and Putnam (1945) fed 14 times the recommended amount of a strong-smelling, low-grade sardine oil for 30 days and found that the eggs had no fishy odor or flavor and could not be distinguished from the eggs of chickens on other rations. Nilsen (1954) fed 1%, 2%, and 8% menhaden oil. The eggs were satisfactory except that some of the eggs from chickens fed 8% oil had a slight off-flavor.

Carcass Quality.—Carcass quality is measured by the flavor, color, odor, texture, and moistness of the meat and by its stability during storage. The texture and moistness of poultry fed fish oils are excellent.

Flavor, odor, color, and stability of the carcasses of chickens fed fish oils will be adversely affected unless caution is used. These changes result from altered depot fat which in turn reflects the composition of the fat in the diet (Cruickshank 1934, 1939; Edwards and Marion 1963; Hilditch *et al.* 1934; Hilditch 1947; Hite *et al.* 1949; Klose *et al.* 1952).

Fishy flavors and odors in poultry flesh have been demonstrated many times during the last 40 years (Carrick and Hauge 1926; Carlson *et al.*

1957; Dansky 1962; Ewing 1943; Hardin *et al.* 1964). Unsaturated fats other than fish oils can also cause development of these off-flavors (Klose *et al.* 1951). In the case of fish oils, not more than one per cent of a fresh oil should be fed to chickens. The recommendation sometimes is made to remove fish oils from the diet for 2 or 3 weeks prior to slaughter. It is interesting to note that fishy flavors apparently do not develop from feeding even high levels of fish meals. The problem arises when extracted oils are fed.

Turkeys seem to be more affected by fish oils in the diet than chickens. Asmundson *et al.* (1938) found fishy flavors in two out of four turkeys fed 1% fish oils. Klose *et al.* (1953) reported a slight amount of fishy flavors in carcasses from turkeys fed 0.4% sardine oil and an intense fishy flavor from turkeys fed 2% sardine oil.

Marble *et al.* (1938) also reported fishy flavors and odors in turkeys fed 1% cod liver oil. When the fish oils were removed from the diet eight weeks prior to slaughter, the fishy flavors were not noted. Marsden *et al.* (1952) found the fishy flavor more persistent when larger amounts of oil were fed. The diets contained 14% whitefish meal plus 0.375% fortified cod-liver oil or 8% sardine meal plus 2% straight cod-liver oil. Fishy flavors persisted for 13 weeks after the fishery products had been removed from the diet.

Stability of Poultry Products.—One of the problems of the poultry industry is development of oxidative rancidity during frozen storage of the products. This limiting factor in the stability and storage life of the product is affected by the composition of the depot fat. Stability decreases with an increase in total body fat and/or in the amount of unsaturated fat present. Klose *et al.* (1952) correlated the induction period of the fat with its fatty acid composition. They compared the induction period of gizzard depot fat from turkeys fed different dietary fats and found the shortest induction period (less stability) in birds fed two per cent sardine oil. This confirmed the results of Schreiber *et al.* (1947) that feeding two per cent fish oil for two weeks prior to slaughter decreased the stability of the carcass toward oxidative rancidity.

Swine

Pigs can assimilate fish oils and utilize them for energy, but the amount must be limited to maintain the quality of the carcass. Ellis and Isbell (1926) showed that the character and composition of the depot fat of hogs was affected by the fat in the ration and that too much oil in the ration caused soft pork. Brown (1931) fed 14% menhaden oil for five weeks prior to slaughter and found that 2.7% of the highly unsaturated fatty acids was deposited in the fat of the pigs. The fat in the carcasses had a

marked yellow color. He concluded that the pig utilizes the more highly unsaturated fatty acids and stores the remainder. Banks and Hilditch (1932) fed 7% fish meal which was equivalent to 0.7% fish oil and found that the lard contained 1-2% of the highly unsaturated C₂₀ and C₂₂ fatty acids. Oleic and linoleic acids appeared to be stored more freely than the highly unsaturated fatty acids.

The British National Institute for Research in Dairying (Anon. 1934, 1937, 1939) fed swine a diet containing ten per cent herring meal or an equivalent amount of crude herring oil without producing fishy flavor in either the bacon or the pork. When this was increased by feeding 10% defatted fish meal plus herring oil equivalent to 20% fish meal, the bacon and ham had a definite fishy flavor and the pork was of poor quality. Results indicated that the pork was good if herring oil in the diet did not exceed 0.5%. Fraser *et al.* (1934) fed 1/2 to 1 ounce of cod-liver oil or sardine oil daily for 130 days. Pigs slaughtered immediately had a fishy taste, but this was prevented by discontinuing the oil for 30 days before slaughter.

Callow and Lea (1939) and Lea (1936) fed ten per cent cod-liver oil to pigs and, in addition to fishy flavors in the pork fat, found that the fat was more susceptible to oxidation. Husby and Haug (1938) recommended that bacon pigs should not be fed more than ten grams of fish oil per day because the bacon would develop fishiness during storage. They stated that problems of fishy flavors and soft, yellow fat could be eliminated by discontinuing use of all fish ingredients in the diet six weeks before slaughter of the animals.

Garton *et al.* (1952) studied a pig that had received 50% of crude whale oil from the time it was weaned. Growth and health of the pig were normal. The whale oil fatty acids were deposited in the fat, particularly in the outer back fat, and the fat was a yellowish-brown. Fractional crystallization showed that 26% of the fat was similar to whale oil in composition. The whale oil triglycerides appeared to be deposited without any alteration.

Anglemier and Oldfield (1957) fed pilchard oil at levels of 2.75%, 5.5%, and 8.25%. Pigs fed the highest level failed to eat and growth was unsatisfactory. Growth performance and feed efficiency were satisfactory at the two lower levels. The carcass fat of the pigs in all of the diets had a fishy odor and flavor and a yellowish tinge. Oldfield and Anglemier (1957) also investigated the effects of modified menhaden oils on the quality of carcass fats. They fed five per cent of crude, of alkali refined and bleached, and of polymerized oil. Carcasses from the pigs fed polymerized oils were not discolored and had improved flavor and odor, but growth of the animals was poor. Possibly oil polymerized under the cor-

rect conditions could be both nutritionally adequate and permit good growth.

Since the fat in the carcass of pigs is affected by fish oils in practical rations, the recommended level for feeding fish oils is about 0.5% in the ration. Another precaution is to remove the fish oil from the diet for a period prior to slaughter. The time recommended varies from two weeks to four months. Removal of fish oil when the pig reaches 100 pounds live weight has also been recommended.

Cattle

Beard *et al.* (1935) and Thomas *et al.* (1934) fed menhaden oil to steer calves and found that color, firmness, and palatability of the beef fat were not affected. Reports of effects of fish oils on growth are both favorable (Davis and Maynard 1938) and unfavorable (Madsen *et al.* 1935; Nicholson *et al.* 1962). Results obviously are related to the amount of oil given (Leach and Golding 1931; Turner *et al.* 1936), to the rest of the ration, and particularly to the amount of vitamin E in the diet.

A number of reports about detrimental effects of cod-liver oil on calves have appeared in the literature, Blaxter *et al.* (1953A, 1953B, 1953C) showed that the muscular dystrophy caused by cod-liver oil was due to the unsaturated fatty acids of cod-liver oil and was prevented when the diet contained adequate vitamin E.

Fish oils in the diet of dairy cows can be used to reduce the butterfat content and to increase the amount of unsaturated fatty acids in milk. Brown and Sutton (1931) reported that menhaden oils lowered milk production, the percentage of butterfat, and total butterfat. Small quantities of the highly unsaturated fatty acids passed from the menhaden oil into the butterfat and analytical constants of the butter changed to those of a mixture of butter and menhaden oil. Effects on milk production and butterfat content have been noted from whale oil (McDowall *et al.* 1957) and cod-liver oil (Davis and Maynard 1938; Hilditch and Thompson 1936; McCay and Maynard 1935; Mattick 1928; Petersen 1932).

Graham and Cupps (1938) fed herring oil to goats and observed a similar effect on milk production. Hydrogenated herring oil did not reduce the percentage of milk fat. McCay *et al.* (1935, 1938) reported that hydrogenated cod-liver oil, salmon oil, and shark-liver oil had little or no effect on milk production. Fountaine and Bolin (1944) and Blaxter *et al.* (1946) reported that shark-liver oil did not affect milk yield, butterfat production, or health of the cows. Maynard *et al.* (1936) found that the iodine value of the milk is influenced by the degree of unsaturation of ingested fat.

Cod-liver oil not only lowers the fat content of the milk but also changes

the proportion of volatile fatty acids in the rumen: propionic acid increases, and both acetic acid and butyric acid decreases (Nicholson *et al.* 1963; Nottle and Rook 1963; Shaw and Ensor 1959).

Mink

Fish oils as such are not incorporated into diets of mink, but fish or fish scraps often constitute a large part of their diet. When the diet consists principally of fish the fat content is low and lard or tallow is added. In the past, mink often were affected by steatitis or yellow fat disease, but research studies have established the etiology of the disease and it easily can be prevented. The condition has been associated with feeding rancid horse meat, linseed oil, or fish, or with a diet containing a low level of vitamin E and a large amount of unsaturated fatty acids. Thus the mink rancher prevents the difficulty of adding adequate vitamin E to the diet and feeding non-rancid horse meat or fish (Gorham *et al.* 1951; Hartsough and Gorham 1958; Lalor *et al.* 1951).

Pet Foods

Cats also develop steatitis when they have been fed exclusively on fish for a long period without the addition of vitamin E to the diet. Coffin and Holzworth (1954), Cordy and Stillinger (1953), and Munson *et al.* (1958) reported that cats develop steatitis from a prolonged exclusive diet failed to grow when fed five per cent of crude tuna oil and only 17 IU vitamin E was added to the diet (Cordy 1954; Cordy and Stillinger 1953). This condition is a vitamin E deficiency aggravated by the polyunsaturated fatty acids in the oil. Gershoff and Norkin (1962) showed that kittens failed to grow when fed five per cent of crude tuna oil and only 17 IU vitamin E/kg. When they included 425 IU vitamin E/kg. with five per cent crude tuna oil, the cats grew normally and no histologic abnormalities were present after ten months. They found that vitamin E gave complete protection against steatitis for 13.5 months, the maximum length of their feeding experiments. Scott and Humphreys (1961) fed large amounts of herring oil, up to 30 gm. daily, representing 64% of their dry food intake, to kittens for 15 weeks. They grew well and were in good health. At the end of the experiment, the abdominal fat of one cat had some yellowish discoloration. No other abnormality was noted.

Steatitis should no longer be a problem in cat nutrition because vitamin E is routinely added to processed pet foods and recommendations are made that cats be fed a mixed diet.

SUMMARY

Fish oils contain a broad spectrum of fatty acids that are well utilized by animals. When used properly fish oils permit good growth, have high

levels of metabolizable energy and of digestibility. Oxidized fish oils with high peroxide values should not be fed because of the detrimental effects of the peroxides. The vitamin E requirement for most animals is increased when fish oils are added to their diets. When the animals are to be used for food purposes the amount of fish oil fed must be limited to prevent occurrence of fishy flavors.

More research is needed to determine to role of fish oil in lipid metabolism and the inter-relationships not only with vitamins and amino acids but also among the many fatty acids.

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