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THE ROLE OF FISH MEAL IN DIETS FOR POULTRY

by
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Summary: Reports of comparisons of the performance of poultry fed diets with and without fish meal, appearing in world literature in the last decade, have been reviewed. Most classes of poultry (broiler, breeder, layer, turkey poult and turkey eeder) are included.

Emphasis has been placed on those experiments in which the diets were nutritionally balanced to at least the extent that is currently possible by feed mixing companies using computer techniques.

The average responses to dietary fish meal inclusion, compared to an all-vegetable protein diet, were as follows:-

Broilers	3.9% fish meal inclusion	1.9% improvement in feed conversion 2.4% improvement in growth
Turkey Poults	5.0% meal inclusion	2.8% improvement in feed conversion 3.6% improvement in growth
Layers	4.2% inclusion of fish meal	15.4% improvement in feed conversion 4.2% increase in number of eggs

In case of breeding hens and turkeys, inclusion of fish meal in the diet improved egg fertility and hatchability, though the extent of the improvement varied.

Possible reasons for the improved productivity of poultry fed diets containing fish meal are discussed.

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FISH MEAL SCIENTIFIC ADVISORY SERVICE

The International Association of Fish Meal Manufacturers (IAFMM) announces the establishment of a permanent Scientific Advisory Service mainly for Feed Compounders and Concentrate Manufacturers and Agricultural Institutions. The staff of the IAFMM, in conjunction with its Scientific Committee, representing an international group of experts in nutrition, bacteriology, engineering and product development, will provide up-to-date information on any aspect of Fish Meal and its uses. All enquiries should be directed to:

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1. INTRODUCTION

In recent years the widespread use of computers for feed formulation has resulted in raw material usage being determined largely by economic assessment. Linear programmes have been used to indicate which combination of raw materials will meet a given ration specification at least cost. The success of this approach has been largely governed by the practising nutritionist constraining material inclusion etc. to ensure that the final formulation is both nutritionally and economically acceptable and will give optimum animal performance.

It is, nevertheless widely recognised that despite the use of 'synthetic nutrients', the inclusion of some fish meal in poultry feeds is one of the best ways of ensuring success in optimising performance. Consequently it is widespread practice to include fish meal at or above a minimum level.

With recent high feed prices and almost unprecedented narrow margin of return over feed costs, high efficiency of conversion of feed into animal product is of paramount importance. Maximum efficiency is not necessarily achieved using a truly least cost feed. It is on the basis of past experience of the benefits which fish meal inclusion has on feed conversion that nutritionists are prepared to incorporate this raw material, even though the price of the resulting formulation may be above the least cost, i.e. it may apparently cost money to force fish meal into the formulation when only the limited range of nutrients usually considered by the computer is taken into account.

Many experiments have been carried out throughout the world to investigate the role of fish meal in rations for poultry and pigs. The improvements in the processing and quality control of both animal and vegetable proteins for animal feeds, and the far more comprehensive nutritional balancing of feeds possible in the last decade, are thought by some to have altered the role of fish meal. This paper sets out to review recent experiments and to consider critically whether this role has changed.

2. FISH MEAL IN CHICKEN DIETS

2.1. BROILER DIETS

Many of the experiments investigating fish meal in broiler rations have compared the effects of replacing fish meal by soyabean meal to produce a diet in which all of the protein is of plant origin. In most of the recent experiments the diets are fully balanced for energy, protein, minerals and vitamins, as calculated from tables of average raw material composition. In some cases amino acid levels are also balanced but usually this is done for methionine and lysine only. These two amino acids are available commercially in synthetic form, and this can be taken into account in linear programming exercises to arrive at least cost formulations. As they are usually the first two limiting amino acids it is generally felt that if adequate levels of these are provided then levels of other essential amino acids will not restrict performance. The justification for this simplified approach to ensuring an adequate and balanced supply of the essential amino acids will be considered later.

In evaluating a raw material which is primarily a source of protein, the response obtained will obviously be affected by the intake of other nutrients in relation to requirement. For example, if energy intake is limiting then differences in source of protein may have no effect on performance.

The actual intakes of energy and protein will be governed by their concentration in the feed and feed intake. Because broilers are fed *ad libitum* and tend to eat an amount of feed providing approximately the same amount of energy, the weight of food eaten is inversely related to energy concentration. Energy concentration is therefore important in terms of its ratio to protein and also in terms of its effect on feed intake, both factors affecting the efficiency with which dietary protein is utilised. Some of the protein in a very high protein diet may be used as an energy source rather than providing the essential amino acid building blocks at the sites of protein synthesis.

The concentration of total protein fed will also affect differences due to protein source. When a diet with excessive protein is fed, protein quality becomes less critical. The limiting essential amino acids will tend to be provided by virtue of the high quantity of protein present but a proportion of other non-limiting amino acids, which will be present in excessive quantities, will be wasted, resulting in an inefficient overall use of protein. In consequence, protein sources are most critically evaluated at a number of energy and protein intakes. By so doing, numbers of treatments tend to become very large and so it is perhaps not surprising that in most experiments intakes of energy and protein are fixed. In a limited number of experiments, two or more energy or protein intakes have been used. This is a particularly useful approach for the reasons given above and also because response to energy or protein will in most cases indicate that nutrition is limiting performance rather than say adverse environment or poor genetic capacity of the stock used etc. Experiments in which proteins have been assessed at two or more concentrations of energy or protein will be reviewed first.

Recently De Groot (1973) in Belgium compared a series of diets with and without 2% white fish meal (65% crude protein), the level of dehulled soyabean meal (50% crude protein) being increased in the latter diets. The diets were formulated at five energy concentrations - 3,000, 3,100, 3,200, 3,300 and 3,400 kcal metabolisable energy (ME/kg) and designed to provide the same nutrients including amino acids. The starter rations fed up to five weeks contained 22% crude protein and the finisher ration fed after five weeks 20% crude protein. Because meat meal was included with the starter rations with the highest energy level (3,400 kcal ME), the comparision of feeds with and without fish meal must be restricted to the other four energy levels. The six week weights increased progressively and significantly with increasing energy concentration - 1,178, 1,210, 1,223, and 1,275g for diets with 3,000, 3,100, 3,200 and 3,300 kcal ME/kg. respectively. There was no difference in weights at six weeks or feed conversion for the treatments with or without fish meal - 1,213g, 1.88 and 1,222g, 1.87 respectively (mean values for four energy levels). All feeds were based on milo. There was no indication whether or not this was checked for tannin content. There have been reports of milo containing levels of tannin which when fed have affected growth.

In the experiment carried out by Hartel *et al.* (1968) in Germany, fish meal (3.7 or 4.7%) in rations with 20 or 26% crude protein and 3,330 kcal. ME/kg. was replaced with dehulled soyabean meal. Three grades of fish meal were used:

Grade of fish meal	Crude protein %	Available lysine g/16gN
Good	65.0	6.8
Medium	64.5	6.0
Poor	65.6	5.5

The substitution was carried out on a total protein basis at the two protein concentrations keeping energy concentration the same. Additionally, all rations were compared with and without supplementary methionine (approximately 0.1%). Unfortunately, because only limited quantities of tested fish meals were available, the trial was restricted to an 11 day feeding period. The feed conversion results were as follows:

			Feed Conversion	
Protein Source		Methionine Supplement	Protein 20%	Concentration 26%
Soyabean meal		0	1.77	1.57
		+	1.59	1.44
		Mean	1.68	1.50
Fish Meal	Poor Quality	0	1.82	1.50
		+	1.58	1.45
		Mean	1.70	1.48
	Medium Quality	0	1.76	1.50
		+	1.58	1.43
		Mean	1.67	1.47
	Good Quality	0	1.65	1.51
		+	N.A.	1.42
		Mean		1.46

These feed conversions were arrived at by correcting to uniform feed consumption. The justification for this is not really clear. Chicks receiving the higher protein diet used their feed significantly more efficiently. All rations responded to methionine supplementation, the concentrations in the unsupplemented rations being rather low:

20% protein ration - 0.27% methionine
26% protein ration - 0.37% methionine

Comparing the methionine supplemented rations, feed conversion was similar at the low protein concentration for the different proteins (the result for the good protein is not available) and at the high protein concentration, yet for all the proteins, the higher protein concentration resulted in significantly better feed conversion. It is surprising that improving protein quality and therefore supply of limiting amino acids at the low protein concentration had no effect, yet increasing the level of all amino acids, brought about by increasing protein concentration, improved feed conversion.

Hartel concluded that provided the rations were supplemented with methionine, performance was similar for the different protein sources at a given protein concentration. Possibly the milk powder (2%) included in all feeds helped provide essential amino acids so that quality of the additional protein was not critical in the presence of additional methionine, though this doubtful in view of the response from the additional protein. Of course, in the ration containing no fish meal, animal protein was still present.

In an earlier experixent (Hartel 1968) carried out along similar lines to that just described (Hartel *et al.* 1968), levels of fish meal of up to 10% in diets containing 22 or 26% protein were replaced with soyabean meal. Good quality fish meal was used, and the chicks were on trial up to 35 days of age. Results expressing weight increases corrected for 900g feed intake (again the basis for this correction is not clear) show progressive decline in weight gain and hence feed conversion as fish meal content is reduced:

	Level of Fish meal				
	9.3%	7.0%	4.7%	2.4%	0
22% Protein ration Weight Gain g.	507	517	507	488	424
	10.9%	8.2%	5.5%	2.8%	0
26% Protein ration Weight Gain g.	560	556	545	511	448

As in the other experiment (Hartel *et al.* 1968) feed conversion was better at the higher protein level, and this applied even with 9% fish meal. At the low protein concentration feed conversion below 2.4% fish meal declined drastically. At the high protein concentration feed conversion declined below 5.5% fish meal. No supplementary methionine was used in this trial and undoubtedly much of the response to fish meal is due to the extra methionine contributed, as was confirmed in the trial described above (Hartel *et al.* 1968).

In a recent trial at Iowa State University, successively higher levels of corn/anchovy fish meal completely replaced dehulled soya in broiler diets of 12, 15, 18 and 21% crude protein (Avila and Balloun, 1974). The diets were isocaloric (3036 kcal ME/kg), balanced for calcium and phosphorus and fortified with minerals and trace elements. Amino acids were not balanced. The results are not reviewed in this bulletin because the levels i of fish meal used were generally much higher than those adopted in practice and also there is evidence that the anchovy fish meal used in this study was not representative of normal commercial production.

In Norway Herstad (1973) has reported a series of experiments with broilers fed rations containing different levels of Norwegian herring meal, fed at two protein concentrations, approximately 21% and 24%. Addition or omission of supplementary methionine (0.1%) were additional treatments. Feeds were isocaloric (3,020 kcal ME/kg), and balanced for minerals. In the first six experiments chicks were grown to ages ranging from four to eight weeks.

Results for feed conversion are summarised below. To simplify these results, feed conversion for the group fed the low protein concentration diet without methionine is expressed as 100% and the high protein concentration and supplementary methionine treatments are expressed in relation to this value. Also, the 0% fish meal treatment value is expressed as 100% and the other fish meal treatments expressed in relation to this value:

	Protein Concentration				% fish meal in diets			
	21%		24%					
	Methionine Supplement							
Expt. No.	0%	0.1%	0	0.1%	0	2	4	8
1	-	-	100	99	100	96	97	93
2	100	96	97	96	100	96	93	90
3	100	96	100	97	100	98	96	92
4	100	95	96	92	100	-	94	-
5	100	95	98	95	-	-	-	-
6	-	-	100	96	100	-	-	-

In all experiments, inclusion of fish meal significantly improved feed conversion and the improvement tended to increase with increasing quantity of fish meal in the diet. Feed conversion was better at the high protein concentration, and methionine inclusion improved feed conversion also. Surprisingly, there was no significant interaction between treatments - response to protein concentration and also methionine supplementation were similar at each level of fishmeal, though response was slightly greater for the diet without fish meal. Inclusion of fish meal gave as great a response at the high as at the low protein concentration. Also, there was a response to methionine even where dietary concentration was highest - in the high protein concentration diet with 8% fish meal, estimated to contain approximately 0.47% methionine (compared with 0.34% methionine in the 21% protein, 0% fish meal diet) using results of analysis given in the paper. Furthermore, Hartel (1968) showed a response in broilers fed diets with 20% or 26% crude protein and 0.28 and 0.37% methionine respectively, when supplemented with an additional 0.1% methionine (see p.4). The latter diet had a high content of methionine in relation to the broilers' requirement and it is surprising that the additional 0.1% methionine did not create an amino acid imbalance and depress performan

In Herstad's work (1973), the first five experiments reported used no supplementary vitamin B12 in the diets and therefore the extent to which response to fish meal was due to its B12 content is not certain. However, in the sixth experiment, the results given (see earlier) are means of treatments with and without this vitamin. The separated results are given below:

	Feed conversion results - Experiment 6			
	0% fishmeal	4% fishmeal	0% methionine	0.1% methionine
Without vitamin B12	2.20	2.06	2.18	2.08
With vitamin B12	2.17	2.05	2.16	2.08

Although feed conversion on the all vegetable diet improved with supplementary vitamin B_{12}, the improvement was not as great as that when 4% fish meal or methionine were included. This suggests that vitamin B_{12} content of the fish meal accounted for only a part of the response brought about by its inclusion in the previous five experiments. This result has been confirmed by results from a later experiment (Herstad, 1974) - experiment 7.

In an experiment to investigate possible unidentified growth Factor effects of sulphur by supplementing dehulled soyabean meal diets with sulphate, methionine or fishery products, Miller *et al* (1974) working in the U.S.A. compared the effect of replacing some of the soya-bean meal with 5 or 10% menhaden fish meal or 5% fish solubles, all diets being kept isonitrogenous (20% CP) and isocaloric (3,280 kcal ME), on chick growth over a 24-day period. Both growth rate and feed conversion improved significantly. Fish solubles also significantly improved these performance criteria, but not to the same extent. Neither methionine nor sulphate supplementation improved weight gains, though methionine brought about some improvement in feed conversion, suggesting that part of, but not all, the response to the fish products was due to methionine contribution. Unfortunately, no supplementary vitamin B_{12} was included, so it is not possible to assess to what extent, if at all, the response to animal protein was due to its contribution of this vitamin. In a second experiment described in this paper vitamin B_{12} was added to diets which were somewhat higher in protein (24%) and lower in energy (3207 kcal ME/kg), to compare the substitution of 5% fish meal or 5% fish solubles for soyabean meal. Again fish meal and fish solubles resulted in significantly better weight gains than an all soya diet (657 g v 680 g v 614 g) but feed conversion was only improved with fish solubles).68 v 0.72 v 0.70 v - gain/feed for fish meal, fish solubles and soya diets respectively).

In this experiment the fish products versus all soya diets comparison is somewhat confused by the addition of 0.3% methionine to all the diets. This would tend to give excessive methionine levels in the fish product diets, and possibly an amino acid inbalance.

Bjornstad *et al* 1974 also investigated a UGF effect when they studied response of chicks to supplementary selenium. This experiment also compared an all vegetable protein diet (mainly soya) with a diet containing 5% capelin meal, both diets being equated for energy, protein, lysine, sulphur amino acids etc. Chicks receiving the diet containing capelin meal had a 4% better growth rate and 3% better feed utilisation than those fed the all vegetable protein diet.

Dameron *et al* (1971) failed to find a significant improvement in growth or feed conversion of bôilers when dehulled soya-bean meal was replaced with 3% anchovy fish meal in isonitrogenous (23% CP) and isocaloric (3,177 kcal ME / kg) diets. The diets were balanced for calcium, phosphorus and methionine content, and a comprehensive trace mineral / vitamin supplement was included in all the diets. Addition of 1.5 or 3% whey, whey plus fish meal or 100 or 200 mg biotin/ton also failed to produce a response in those criteria compared with the basal corn-soyabean meal diet. The basal diet also contained 3% alfalfa.

Day and Dilworth (1965) working at Mississippi State University compared growth up to five weeks of broilers fed balanced diets (22.8% crude protein and 2,200 kcal/kg productive energy) with dehulled soyabean meal only, 1.25, 2.50 or 5.00 Menhaden fish meal (FM) or combinations of fish meal, corn fermentation solubles (CFS) and poultry by-products meal (PBPM). Results (below) show significant improvements in weight and feed conversion for fish meal (5%), fish meal (2.5%) plus corn fermentation solubles (2.5%) and poultry by-product meal (2.5%).

	% in diet			Five week Results	
Diet	CFS	FM	PBPM	Av. wt. g.	Feed/Gain
1	-	-	-	845	1.77
2	-	1.25	-	873	1.74
3	-	2.50	-	882	1.72*
4	-	5.00	-	895*	1.70*
5	2.50	-	-	859	1.76
6	2.50	1.25	-	850	1.75
7	2.50	2.50	-	891*	1.72*
8	2.50	5.00	-	873	1.72*
9	-	-	2.50	891*	1.72*
10	2.50	-	2.50	864	1.71
11	2.50	1.25	2.50	868	1.70
12	2.50	2.50	2.50	877	1.72*

(* significantly different)

Feed conversion was improved 2.8% and 4.0% with the 2.5 and 5.0% fish meal diets respectively compared with the basal corn-soyabean diet. The diet with only 1.25% fish meal gave a small non-significant improvement in growth and feed conversion. Comparing responses to fish meal, corn fermentation products and poultry by-product meal added singly at 2.5%, improvement in growth rate and feed conversion were similar with fish and poultry by-product meals and slightly less with corn fermentation solubles. All diets in this experiment were fortified with a comprehensive trace element/vitamin mixture including vitamin B12, and methionine hydroxy analogue was used to equalise methionine levels.

In a series of comprehensive experiments conducted in Germany a few years ago, Vogt and Stute (1967) investigated the effect on broiler chick growth of replacing fish meal with soyabean meal. In this work the diets were balanced for energy, protein, lysine, methionine plus cystine, minerals and vitamins largely on the basis of actual analysis rather than use of composition tables. In common with most European experiments, the soya used included hull and was therefore lower in protein (46%) and energy and higher in fibre than the dehulled soya used in most of the American work. Diets were formulated with 22% crude protein and 2,877 kcal ME/kg. Fish meal concentrations tested were 6, 4, 2 and 0%. A negative control diet without fish meal, additional amino acids or vitamin B12 was included. Successively lower levels of fish meal were achieved by substituting soyabean meal for fish meal and oats. All diets contained 1% dried milk powder.

	Results at 8 weeks	
	Live weight (g)	Feed conversion (Feed : Gain)
6% fish meal	1,441	2.34
4% fish meal	1,396	2.38
2% fish meal	1,387	2.39
0 fish meal + soya oil	1,384	2.43
0 fish meal + fish oil	1,345	2.44
Negative control + soya oil	1,315	2.54

All the fish meal diets supported better growth and feed conversion than the soyabean meal diet. The negative control treatment was significantly worse than the other treatments. The 6% fish meal diet was significantly better than the soyabean meal diet with fish oil, feed conversion being improved 4.3%, and 3.7% over that for the soyabean meal diet with soya oil.

This experiment was repeated, the main difference being that wheat bran was substituted for oat meal and the bran plus fish meal replaced where appropriate by soyabean meal. Also, levels of potassium and iodised salt were manipulated to equalise contents of the elements they provide in the diets, though in the first experiment they appeared neither inadequate nor excessive. The treatment without fish meal but with fish oil was replaced with a treatment without fish meal but with soya oil, fat soluable vitamins and trace elements. In contrast to the results of the first experiment, there was no improvement resulting from the incorporation of fish meal at any of the levels tested in this second experiment.

	Wt. 8 weeks (g)	Feed conversion
6% fish meal	1,441	2.41
4% fish meal	1,417	2.38
2% fish meal	1,436	2.41
0% fish meal	1,458	2.37
0% fish meal + additional fat sol. vitamins and trace elements	1,475	2.38
0% fish meal without supplementary amino acid and vitamin B12 compensation	1,373	2.50

The negative control - no fish meal and no supplementary amino acids or B12 vitamin, resulted in significantly poorer weight gain and feed conversion. Contary to Vogt and Stute's conclusion that fish meal in broiler rations can be replaced without deterioration in performance, substitution of fish meal with soya bean meal in their first experiment resulted in poorer performance despite the fact that all diets contained 1% dried whey powder. These results indicated that the substitution can sometimes result in reduced performance.

In a later paper the same workers reported similar experiments in which dried whey was omitted from the diets, and soya replaced fish meal plus wheat bran (Vogt and Stute, 1968). Again a negative control diet, excluding fish meal and vitamin B12, was included. Treatments with 1% fish solubles were also included. They whey did not affect the results and no consistent differences were apparent between the animal protein and all vegetable diets, though once again results with the negative control diet were significantly worse.

	Mean results from experiments 1 and 2	
	Weight at 8 weeks g.	Feed conversion
6% fish meal	1,409	2.38
0% fish meal, 1% solubles, 1% whey	1,447	2.35
0% fish meal, 1% fish solubles	1,452	2.34
0% fish meal, 1% whey	1,416	2.39
0% fish meal	1,450	2.34
0% fish meal - without supplement (negative control)	1,318	2.51

There was an indication that the 6% fish meal treatment gave slightly poorer results than either 1% fish solubles or a diet with no fish products. In both experiments eight week weights were rather low. This second experiment would seem to show that good performance can be achieved on all vegetable (soyabean) protein diets as on diets including animal protein.

Rose-Marie Wegner (1968 and 1970), also working in Germany, carried out a series of experiments similar to those of Vogt and Stute, comparing performance of broilers fed diets with 6% fish meal and without fish meal. Unfortunately there was a high incidence of perosis in birds used in the experiments, particularly those in the earlier report (1968). As 27% of the control birds developed perosis, results of in this earlier report (1968) have been discounted.

In the experiments described in the later report (Rose-Marie Wegner, 1970) diets were formulated to be similar to those used by Vogt and Stute, but tables were used for raw material composition. The control diet (6% fish meal) was compared with diets in which fish meal and wheat bran were replaced with soyabean meal (46% crude-protein) with (test diet I) and without test diet II) supplementary salt. As in Vogt and Stute's work, diets were isonitrogenous (22% crude protein), isocaloric (2915 kcal ME/kg) balanced for minerals, and a comprehensive vitamin supplement used. Details of supplementary trace elements used are not given. In the two trials growth and feed conversion of the broilers to eight weeks of age was better on the control (6% fish meal) diet:

	Mean 8-week results for two experiments:	
	Live weight g.	Feed Conversion
Control (6% fish meal)	1,706	2.24
Test Diet I (0% fish meal plus salt)	1,646	2.32
Test Diet II (0% fish meal without salt)	1,633	2.30

The differences between the control and test diets appraoched significance. Unfortunately the incidence of perosis in this experiment was rather high - up to 15% in the control group in one experiment, though this is not as high as in a previous similar experiment referred to earlier (Rose-Marie Wegner, 1968). Choline deficiency is unlikely to have caused the deficiency as a supplement of 200 g/ton choline chloride was added. The amount of supplementary manganese added, if any, is not stated. Consequently, the marked improvement in performance on the fish meal diet has to be interpreted with reservation in view of the disease problem, though the eight week weights of the birds were quite good - better than those achieved in Vogt and Stutte's experiments. Rose-Marie Wegner concluded that it is not always possible to obtain the maximum performance with poultry by fortifying all-plant protein diets.

TABLE 1 – SUMMARY OF RESULTS OF BROILER EXPERIMENTS COMPARING DIETS WITH AND WITHOUT FISH MEAL

Fish Meal Type	Level in Diet %	Feeding Period Days	Number of Birds/Test Diet	% Improvement in Liveweight compared with all-veg. diet	% Improvement in Feed Conversion compared with all-veg. diet	REFERENCE
Herring	4	0-56	64	4.7	5.5	Herstad, 1973[1]
Herring	5	0-49	120	4.0	3.0	Bjornstad *et al*, 1974
White Fish	2	0-42	72	0	0	De Groote, 1973[2]
Anchovy	3	0-56	80	0.7	1.1	Dameron, *et al*, 1971
Menhaden	1.25	0-35	40	3.3	1.7	Day and Dilworth, 1965
Menhaden	2.5	0-35	40	4.4	2.8	
Menhaden	5	0-35	40	5.9	4.0	
Unknown	2	0-56	128	0.6	0.2	Vogt and Stute, 1967[3]
Unknown	4	0-56	128	0	1.1	
Unknown	6	0-56	128	4.8	1.3	
Unknown	6	0-56	128	-2.8	-1.7	Vogt and Stute, 1968[4]
Unknown	6	0-56	120	3.6	3.4	Wegner, Rose-Marie,1970[5]
MEANS	3.9			2.4	1.9	

Results excluded from means (see notes)

Fish Meal Type	Level in Diet %	Feeding Period Days	Number of Birds/Test Diet	% Improvement in Liveweight	% Improvement in Feed Conversion	REFERENCE
Fish solubles	3	0-28	100	16.2	8.7	Hinton and Harms, 1972[6]
Unknown	4	0-11	76	0	1.4	Hartel *et al*, 1968[7]
Unknown	5	0-35	200	13.8	approx. 20	Hartel, 1968[8],
Unknown	5	0-26	36	7.0	2.8	Miller *et al*, 1974[9]
Fish solubles	5	0-26	36	10.7	-2.8	

Explanatory Notes :-

1. Results from experiment 6 where vit. B12 was added.
2. Result from diet with 3,400 kcal excluded because meat and bone meal included in this diet.
3. All-veg. diet supplemented with sulphur amino acids and vitamins including B12 (treatment (IV).
4. Treatments I v. IV. Other treatments with whey or without supplementary amino acids.
5. All vegetable diet plus salt (treatment I) compared with fish meal diet.
6. Comparison based on diets without sulphate supplement.
7. Comparison of vegetable diet and 'good' fish meal, each supplemented with methionine. Valuves taken for 26% CP diets only – no value for 20%. All diets low in methionine and not balanced.
8. Diets with fish meal compared to those without; diets with low levels of fish meal and especially those without were low in methionine.
9. Results from Experiment 2. 0.3% methionine added to all diets – may have been excessive.

Summary of Results

In the many experiments reviewed so far, each one has compared growth of broilers fed diets with and without fish meal under a variety of circumstances in different parts of the world. In all these experiments, the fish meal and indeed other feeds used were ascribed a nutritive value, and diets were forumulated to be nutritionally equivalent on the basis of these values. Results were variable - in some experiments chicks receiving diets containing fish meal performed significantly better than those receiving an all-vegetable protein diet: in other experiments this was not so. It must be remembered, of course, that a no-difference result indicates that the birds responded as predicted from the nutritive value ascribed; an improvement implies a response greater than predicted.

The results of the experiments described so far are summarised in table 1. They represent a comparison of live weight gain and feed conversion of chicks fed diets with and without fish meal. For convenience the results for the fish meal diets have been expressed in the form of the percentage difference relative to the all-vegetable protein diet.

The results which are not in brackets are those where diets appear to have been fully balanced nutritionally, as would be possible in commercial practice.

The results were very variable. Of course the experiments were very different in terms of environment, type of chick and diet specification. Nevertheless, these differences probably reflect those which occur in practice. For this reason, mean values have been calculated from the results tabulated, excluding bracketed results.

The inclusion of fish meal gave a mean improvement in feed conversion of 1.9%. It is not possible to draw general conclusions with regard to the effect of amount of fish meal in the diet on feed conversion, but the mean overall level in these experiments was about 4%.

Because most of the experiments do not compare results of different periods up to eight weeks of age (most give a result for the whole eight week period), it is not possible to compare effects of fish meal at different growth stages.

In conclusion, there is recent experimental evidence to indicate that in most situations, but not all, chicks fed diets with fish meal grow faster and utilise feed more efficiently than those on an all-vegetable diet.

From recent experiments carried out in different parts of the world to investigate the effects of including fish meal in corn/soyabean meal broiler diets where diets were balanced as far as possible in commercial practice, the overall indication is that by incorporating 4% fish meal, feed conversion will improve by approximately 2%.

2.2 FISH MEAL IN CHICKEN BREEDER DIETS

Investigations of the effect of including fish meal in chicken breeder diets on hatchability, carried out some years ago, gave variable results. Some workers found hatchability was improved (Linstrom *et al.*, 1949). Others found hatchability was depressed (Black *et al.*, 1954; Coles, 1956; Martin *et al.*, 1960).

There are few reports of similar investigations in recent years. March *et al.*, (1967), in an experiment conducted over three years and involving 66,460 eggs hatched, compared breeder diets with soyabean meal, British Columbia herring meal or Atlantic coast white fish meal as sources of supplementary protein. Diets were isonitrogenous, calcium and phosphorus contents were equalised, but they do not appear to have been balanced in other respects. A comprehensive mineral/vitamin supplement including 2.2 mg vitamin B12/kg of diet was used. The fish meals completely replaced soyabean meal, relatively high levels of inclusion being used (10%). Overall hatchability of fertile eggs from diets supplemented with soyabean meal, herring meal and white fish meal was 87.4, 88.3 and 85.7% respectively. The slightly lower hatchability obtained with the white fish meal diet was significantly different in one of the three experiments conducted.

Much lower levels of fish meal (3%) were used in an experiment conducted by Cooper and Hughes (1974). They fed 240 S.C. White Legorn hens a diet based on corn/soyabean meal or corn/soyabean meal/Peruvian anchovy fish meal. The replacement of soya with fish meal was done on an isonitrogenous basis - diets were not balanced in other respects. Hens were housed in wire cages, colony cages or slat-litter floors. Hatchability of fertile eggs from hens fed the vegetable and the fish meal diets housed in cages, colony cages and floor pens were 90.9, 90.0; 92.4, 91.5; 94.9, 93.8 respectively. Hatchability was not affected by protein source, though it was significantly higher ($P<0.05$) for eggs from hens on the floor.

In the experiments carried out by Opstvedt and Gjefsen (1975) White Plymouth Rock hens were fed diets containing 0,2% or 4% Norwegian fish meal and fertility and hatchability of the eggs produced measured. The diets were isonitrogenous (15.0% C.P.), isocaloric (2850 N.E. kcal/kg), and balanced for lysine, sulphur amino acids calcium and phosphorus. Hens fed fish meal diets produced more eggs, more settable eggs and hatchability was increased, all these differences being significant:

Fish meal in diet	4%	2%	0%	SEM
No. hens started	180	180	180	-
Production (hen-day basis)%[1]	48.4	46.8	45.7	0.5
Total no. eggs/hens started on experiment	149	148	142	5
Average egg weight g.[1]	62.8	63.4	63.6	0.1
Fertile eggs %	82.6	79.8	70.0	2.5
Hatchability (% of fertile eggs)	87.7	84.6	85.2	1.0
Live weight of hatched chicks (g)	43	44	44	0.3
Feed conversion (kg per kg eggs)	4.52	4.86	4.85	0.078

S.E.M. = Standard error of mean

1 Average of 12 28-day periods.

Inclusion of fish meal in the diets caused a significant increase in hen-day egg production, number of settable eggs and in the efficency of food conversion though mean egg weight was decreased significantly. Hatchability and fertility were also increased significantly. The inclusion of 2% fish meal improved fertility but not hatchability or feed conversion, whereas all these parameters were improved by addition of 4% fish meal. Opstvedt *et al* concluded that these results further demonstrate the presence of growth factors in fish meal which have not yet been identified.

In conclusion, experiments to investigate the effect on hatchability and fertility of including fish meal in the diets of breeding hens have shown a variable response. In the few experiements conducted during the last decade, where diets were balanced, herring meal significantly improved both fertility and hatchability when included at 4% in the diet.

2.3 LAYER DIETS

Trials carried out in Italy (Bonomi and Bianchi, 1971) showed that when 6% Angolan fish meal in the ration of laying birds was substituted with soya plus sunflower meals, egg production over 12 months dropped by about 7%. The birds which were housed on deep litter were fed diets with 6, 4, 2 or 0% fish meal, the soya bean meal (44% crude protein) plus sunflower meal (45% crude protein) increasing in these respective diets. Sunflower meal was used to give similar concentrations of sulphur amino acids in the diets. The diets were isonitrogenous (17% crude protein) isocaloric (2,000 kcal. productive energy/kg) similar in content of lysine and sulphur amino acids, and were supplemented with a mineral vitamin mix. The birds used (1600) were Hubbard Golden Comet of 1800 g live weight. Results were as follows for a 12-month laying period:

	Level of Fish Meal			
	6%	4%	2%	0%
Egg Production %	68.8	68.2	67.5	64.0
Egg Weight g.	61.7	61.7	61.5	61.0
Food consumed per dozen eggs kg.	2.37	2.45	2.41	2.61

Significantly fewer eggs were laid by the birds on the all-vegetable protein diet. Birds receiving the diet with 6% fish meal produced slightly more eggs than those receiving diets with 4% or 2%. Differences in egg weight were small, those of the birds on the all-vegetable protein diet tending to be slightly smaller. Feed conversion was approximately 8% better for the diets containing fish meal.

In Canada, diets containing animal protein (2% fish meal and 3% meat meal) were compared with an all-vegetable protein diet (cereal/dehulled soya) when fed to 17 strains of laying hens randomised over the dietary treatments (Aitken *et al*, 1969). Birds were held in floor pens. Diets were isonitrogenous and supplemented with minerals, vitamins, and DL methionine, but energy content varied somewhat between 2740 and 2830 kcal ME/kg. Results for a 350 day test period were as follows:

	Animal Protein	Vegetable Protein	Animal Protein	Vegetable Protein
Crude Protein %	17.1	17.0	17.5	17.4
ME/(kcal/kg)	2790	2830	2800	2740
Eggs/bird	210	214	221	220
Food/12 eggs (kg)	1.97	1.94	2.01	2.04
Food/kg eggs(kg)	2.82	2.76	2.82	2.86

There were no significant differences in egg numbers, egg size, egg quality feed conversion or mortality. The small differences in feed conversion in the two tests appear to reflect dietary energy content rather than protein treatments. It must be remembered of course that this experiment tested the combined animal proteins (fish and meat) against soya. The actual inclusion rate of fish meal was relatively low (2%).

A similar experiment by Biely and Wood (1071) compared an animal protein diet (2% herring meal, 3% meat meal and 1% whey) with a vegetable protein diet including dehulled soya. Slightly more eggs were produced from the animal protein diet (246 v. 236) and feed required per 12 eggs was better (3.77 v. 4.08) though the differences were not significant. As egg size was similar for the two treatments the feed conversion was approximately 8% better for the animal protein diet. As in the previous trial the fish meal is contributing less than half the animal protein in this treatment.

In Germany, Vogt (1968) carried out a trial with 81 HNL pullets in batteries and 240 Master hybrid pullets on deep litter. The experiments were designed to compare a diet containing 6% fish meal with an all-vegetable protein diet containing soyabean meal. A negative control treatment (all vegetable protein without amino acid or vitamin B supplementation) was also included. The three diets were isocaloric (2651 kcal/kg) and isonitrogenous (17% crude protein). The diets for the first experiment in cages were formulated on the basis of actual analyses; those for the second experiment on deep litter were based on tabulated values. Results of the first trial are given below:

Group	6% Fishmeal	No Fishmeal	No Fishmeal amino acid or Vit. B
Feed (hen/day)	129.1	130.9	135.6
Egg production (52 weeks)	218.9	238.6	240.6
Egg weight	59.5	59.7	59.9
Feed conversion (per kg. eggs)	3.47	3.22	3.29

None of these differences was significant, which is perhaps not surprising in view of the small number of birds used (27 per dietary treatment). These results contrast with those in the second experiment which used 120 birds per dietary treatment in that egg numbers and feed conversion were similar for the treatments with and without fishmeal:

	6% Fishmeal Diet	No Fishmeal Diet
Feed (per hen/day)	123.8g	124.6g
Eggs produced per hen (323 day period)	210.6	210.9
Mean Egg weight	57.6	57.7
Feed conversion (Feed (kg)/kg egg mass)	3.30	3.31

Performance was the same for the diet with 6% fish meal and that without fish meal but with supplementary vitamins and methionine.

In the U.S.A. Bearse (1971) investigated the laying performance of White Leghorn birds fed diets with 0, 5% or 10% of the following fish meals - British Columbia Herring, Pacific Ocean Hake, Norwegian Herring and Peruvian Anchovy, Diets were isonitrogenous (17% crude protein) and isocaloric (2823 kcal ME/kg), and balanced for minerals/vitamins. Although not stated, it is likely that supplementary methionine was used with the all-soya diets. Only results for the 0 and 5% levels of fish meal are available for a 52 week laying period:

	Eggs per bird	Feed conversion kg/doz. eggs
British Columbia Herring (5%)	256.5	1.70
Pacific Ocean Hake (5%)	261.2	1.68
Norwegian Herring (5%)	256.8	1.79
Peruvian Anchovy (5%)	255.0	1.75
No Fish Meal (cereal/soyabean)	247.1	1.85

Differences in feed conversion between the diets containing fish meals and the corn/soyabean meal diet approached significance. Differences between fish meals were not significant. Eggs from birds fed the herring fish meals were slightly heavier (1g) than those from other treatments. Full details of egg size and quality are not given.

Only one experiment appears to have been conducted to compare diets with and without fish meal at different protein concentrations (Solberg, 1971). This experiment compared:

(i) dietary crude protein concentrations of 13 and 16%.

(ii) diets with (5%) and without herring meal.

(iii) diets with (0.1%) and without supplementary methionine.

(iv) diets with (0.1%) and without supplementary lysine.

The diets were low in energy, the fish meal diets tending to be higher in energy than the non-fish meal diet (2520 v. 2455 kcal ME/kg respectively). All diets were supplemented with minerals/vitamins. Results are given below:

	Protein in diet		Fish meal in diet		Methionine		Lysine	
	13%	16%	0%	5%	0%	0.1%	0%	0.1%
Laying intensity - 32 week period, corrected to 57g eggs	73	74	75	72	74	73	73	75
Feed energy conversion ME/kg eggs.	7.7	7.6	7.7	7.6	7.6	7.7	7.8	7.5

Because of the form in which Solberg expressed his results (as above) it is not possible to check treatment interactions, though none of the differences were significant - only 24 birds per treatment were used. Although the fish meal comparison is given, the figures do not indicate how this was affected by methionine supplementation. This would be important in view of the low methionine content of soya bean meal and cereal / soyabean meal diets. Consequently the results as presented in this paper are not satisfactory. Furthermore, all dietary energy levels were low, and the fact that diets were not isocaloric would confuse the protein comparisons. Surprisingly, the hens receiving the herring meal diet produced fewer eggs, despite the higher energy content of this diet. Feed conversion was slightly better for the herring meal diet.

In the U.K. Cowper (1972) compared performance of Babcock B300 laying birds fed diets with 5%, 2½% or no white-fish meal with 1368 birds per treatment. Diets were isocaloric (2820 kcal. ME/kg) and isonitrogenous (15.2% crude protein), supplemented with minerals, vitamins, and in the case of the all-vegetable protein diet, supplementary amino acids (methionine and lysine). No supplementary vitamin B12 was used. Results were as follows:

	5% Fish	2½% Fish	No fish
Mortality	18.8	22.1	24.8
Eggs/hen housed	245	239	228
Feed conversion kg/doz. eggs Calculated from production % (Hen housed).	2.23	2.30	2.41

Mortality, which was generally high, was higher for the no fish dietary treatment. This would have resulted in fewer eggs for this treatment. However, the difference in egg numbers on the fish meal diets compared to the all-vegetable protein diets (+ 7.4% and + 4.8% for 5% and 2½% fish meal respectively) are greater than would be expected from differences in mortality and hence hen numbers. Indeed, it may well have been a result of fish meal inclusion in the diets which gave rise to lower mortality on these treatments.

Cowper's experiment has recently been repeated (Cowper 1974) with 1297 birds per treatment. Inclusion of vitamin B12 and selenium were investigated in recent work. A 5% fish meal diet was compared with an all-vegetable protein diet supplemented with amino acids, vitamins and minerals, the same additional vitamin B12 (3.5 ppm) or vitamin b12 (3.5 ppm) plus selenium (0.1 ppm). Diets were formulated as in the previous trial. Results are shown below:

	5% Fish Meal	0% Fish Meal		
		No B_{12} or Se	$+B_{12}$	B_{12}+Se
Mortality	17.5	18.4	19.5	19.7
Eggs/hen housed	250	240	242	243
Production % (hen-day basis)	71.2	68.6	69.3	69.7
Large eggs % of total	35	28	31	33
Food conversion kg per doz eggs	1.92	1.98	1.99	1.98

Mortality in this experiment was again high, but not as high for the fish meal dietary treatment as for the other treatments. Hens receiving the fish meal diet produced significantly more eggs and also converted feed more efficiently than the other treatments. Although egg production was increased slightly by addition of Vitamin B12 and 'Vitamin B12 plus selenium',

TABLE 2

Effect of Incorporating Fish Meal in Diets for Laying Hens – Egg Production and Feed Conversion : Summary of Results

Type of Fish Meal	Level in Diet %	No. Birds per Protein Treatment	Expt. Period (Weeks)	No. eggs Produced per bird	Improvement in no. eggs %	Improvement in Feed Conversion %	Reference
British Columbia Herring Meal	5	Not-stated	52	257	3.8	7.9	Bearse, 1971
Pacific Ocean Hake	5	" "	"	261	5.7	9.1	" "
Norwegian Herring	5	" "	"	257	3.9	3.4	" "
Peruvian Anchovy	5	" "	"	255	3.2	5.2	" "
(Fish Meal	6	27	50	219	-8.3[2]	-7.8[2]	Vogt, 1968)
Fish Meal	6	120	46	211	0	0 *	" "
White Fish Meal	5	1297	56	250	3.3	3.2	Cowper, 1974
White Fish Meal	5	1368	"	245	7.4	7.4	Cowper, 1972
White Fish Meal	2½	1368	"	239	4.8	4.3	Cowper, 1972
(Herring Meal[3]	5	24	32	161	-4.0	1.3*	Solberg, 1971)
Herring Meal[4]	2	80	51	245	4.2	7.6*	Biely and Wood, 1971
Fish Meal[4]	2	2108	50	216	-0.9	0 *	Aitken *et al*, 1969
Angola Fish Meal	2	400	52	251	5.5	7.7	Bonomi and Bian(
	4	400	52	249	6.6	5.7	" " 1972
	6	400	52	246	7.5	9.2	" " " "
Mean	4.2				+ 4.2	+5.4	

1. Based on feed/doz. eggs except for figures marked *
2. Results not included in mean because negative control (no amino acid or vitamin supplement) performed better than positive control (with amino acid and vitamin supplement). Also, number birds per treatment was low.
3. Results not included in mean because diets were not isocaloric, and number of birds per treatment was low.
4. Diet with fish meal also included 3% meat meal and 1% Whey.

egg production was still significantly lower than that for the fish meal treatment. This result indicates that vitamin B_{12} and selenium content of fish meal accounted for only a small part of the response due to fish meal inclusion in the diet. Although egg weights were not recorded, eggs were graded by size and there was a greater proportion of large eggs for the birds fed fish meal. In a practical economic assessment of the results, despite the higher cost per ton of the fish meal diet, it gave a net profit approximately 50% higher than the non-fish meal diets.

Summary of Results

Egg production and feed conversion data for birds fed diets with and without fish meal are summarised in table 2.

Inclusion of fish meal is seen to have consistently improved both egg production and feed conversion, though some of the feed conversion values do not take into account egg size. Where egg size was reported, there was no indication that it was lower where fish diets had been fed; indeed in some experiments it was higher.

Averaging the responses whown in table 2, a mean level of 4.2% fish meal in the diet gave a mean response of + 4.2% and + 5.4% increase in egg production and feed conversion respectively over the responses obtained with an all-vegetable protein diet.

Discussion

As for broiler chicks, recent reports in the literature show that when fish meal is included in the laying bird's diet performance is improved above that which would be predicted from the nutrient contribution of the fish meal.

There do not appear to have been any recent investigations of the nature of "unidentified growth factors" with reference to the laying bird. Whether the 'gut microflora' theory put forward by Harrison (1972) to explain growth promotion with fish products in broiler chicks applies also to the mature laying bird is a matter for conjecture at this stage.

Whilst a minimum level of 18g protein per hen per day has been recommended and used in practice, much research indicates that 15g is sufficient, provided energy intake is not limiting. The extra portion is fed as insurance. Recently Anderson and Warwick (1974) have examined egg production of birds fed graded concentrations of protein with particualr regard to energy conversion. This work shows that although reducing protein concentration from 18% to 14% improves conversion of feed protein to egg protein, the conversion efficiency of dietary energy falls. This demonstration of the relationship between utilisation of dietary protein and dietary energy is not new. However, what does not seem to have been investigated in depth is how the protein/energy relationship is affected by protein quality. For a given quantity of protein, a superior quality, i.e. a better balance of amino acids, may enhance energy utilisation. This could explain the growth response observed when fish meal is included in rations for layers. It could also mean that it is no longer necessary to feed layers an extra 3g per day of protein if the protein fed has a better balance of amino acids. Further work is required to investigate these aspects of protein/energy nutrition, particularly in terms of production and economic parameters.

Summary and Conclusions

From a survey of recent literature comparing production of laying birds fed diets with and without fish meal, it would appear that fish meal produces a response in production greater than would be predicted from its nutrient contribution.

Further investigations into the protein requirements of laying birds are required to determine how protein quality (i.e. availability and balance of amino acids) affects quantitative protein needs and utilisation of dietary energy.

3. FISH MEAL IN TURKEY DIETS

3.1 TURKEY POULT DIETS

In Germany Tuller (1972) has compared the growth of Royal White turkeys fed dicts containing the following amounts of fish meal (Peruvian Anchovy):

	Starter 1-6 weeks	Grower 7-14 weeks	Finisher 15-18 weeks ♀ 15-25 weeks ♂
Group I	12%	6%	2%
Group II	6%	2%	0%
Group III	3%	1.5%	0%

Fish meal was replaced with soyabean meal (dehulled) in diets designed to be isocaloric and isonitrogenous. Supplementary methionine was used and the diets were balanced for lysine and methionine plus cystine. The crude protein contents of starter, grower and finisher diets were 29%, 24%, and 18% respectively. A comprehensive mineral/vitamin supplement was used, and rations were balanced for calcium and phosphorus.

Results of Tuller's work are tabulated below:

	0 - 6 weeks		
	I	II	III
Liveweight g.	1891	1828	1827
Feed Conversion	1.54	1.55	1.62
	0 - 14 weeks		
Liveweight g.	6323	6102	6150
Feed Conversion	2.21	2.20	2.28
	0 - 18 weeks		
Liveweight g.	8079	7799	7861
Feed Conversion	2.66	2.62	2.69
	19 - 25 weeks (♂ only)		
Liveweight g.	13491	13056	12925
Feed Conversion	5.19	5.05	5.23

Poults in Group I achieved the highest live weights and best feed conversion (except for male birds from 19-25 weeks). With the exception of feed conversion up to six weeks, when poults receiving the all-vegetable protein diet showed significantly poorer feed conversion, differences between groups were not significant with respect to either growth or feed conversion. However, at each stage up to 18 weeks the higher levels of fish meal numerically improved growth rate and feed conversion. When the results were assessed economically, the best financial return was achieved for group II, i.e. 6, 2 and 1.5 fish meal inclusion in starter grower and finisher rations.

In the U.S.A., Potter *et al* (1971 a) has investigated the growth of young turkeys as affected by incorporation of 5 herring, anchovy or menhaden fish meals in the diet. The experiments also investigated dietary incorporation of zine bacitracin and dried bakery products. The diets were based on the following:

	%
Ground yellow corn	37.3
Hydrolysed animal and vegetable fat	5.0
Dehulled soyabean meal (49% protein)	50.0
Meat and bone scrap (50% protein)	2.5
Corn distillers dried solubles	1.5
Defluorinated phosphate	2.5
Ground limestone	0.5
Iodised salt	0.4
Trace mineral mix	0.05
Vitamin and feed additive premix	0.20

The fish meal diets were formed by adding 5% fishmeal plus 3% corn in place of 7.3% dehulled soya bean meal and 0.7% defluorinated phosphate. No details of the composition of the test diets are given, but on the basis of this substitution they could not have been either isocaloric or similar in methionine content. Furthermore, no allowances were made for the differences in composition of the types of fish meal used. On the basis of composition tables the fish meal diets would have contained approximately 70 kcal/kg more metabolisable energy than those without fish meal, fish meal plus maize being superior to soyabean meal in energy content per unit weight. Consequently the significantly better liveweights and feed conversions of the turkeys fed the fish meal diets up to eight weeks of age may have been partly due to the higher energy and methionine content of these diets: (see table 2 in original paper).

	Liveweight	Feed conversion
5% Menhaden	1810	1.79
5% Anchovy	1906	1.82
5% Herring	1840	1.79
0% Fish Meal	1703	1.84

In another similar experiment (Potter *et al.*, 1971 b) these workers compared different levels of fish meal (menhaden), a supplement of methionine and different cereal grains in turkey poult rations. Whilst the diets with different levels of fish meal were designed to be isonitrogenous and isocaloric, the cereals were substituted on a weight basis so that their comparison was essentially a comparison of the overall nutrient contribution of the cereals.

The composition of the test diets is not given. Response to fish meal inclusion was somewhat variable between diets of different cereal content. Overall responses from 0-8 weeks were as follows:-

	Body weight	Feed conversion
8% fish meal	1721	1.97
4% fish meal	1724	1.95
0% fish meal	1707	1.97

From 18 weeks of age, four fish meal levels were used - 0, 3, 6, and 9%. Results from this period were as follows:

	Body Weight Gain (g)	Feed Conversion
9% Fish Meal	3086	4.38
6% Fish Meal	3085	4.35
3% Fish Meal	3098	4.24
0% Fish Meal	3045	4.39

None of the above differences was statistically significant. However, these results suggest that a 4-8% inclusion rate of fish meal in the diet up to 8 weeks and a 3-6% rate thereafter give greatest response in weight gain and feed efficiency.

In a later experiment, Potter (1972) again compared a 5% fish meal diet (herring) with a basal diet containing no fish meal but some animal protein. This basal diet was the same as that used earlier (Potter *et al.* 1971 b) (see above). The fish meal plus corn replaced soyabean meal, so again the fish meal diet would have been higher in energy. Consequently in comparing the diets with and without fish meal, the comparison was not just animal versus vegetable protein sources, and it was also confounded by the energy differences. The increase in body weight and improvement in feed conversion were quite marked for the fish meal diet, as seen in the eightweek results below:

	Body weight	Feed conversion
5% fish meal	2096	1.81
0% fish meal	1800	1.86

Potter and Shelton (1973) evaluated crab meal and also compared herring meal. This trial was again carried out as in previous trials - energy wasn't balanced so that any response to fish meal would reflect not only its effect in promoting growth but also its superior energy value relative to soya which it replaced. In this trial the basal diet contained only vegetable protein. Results were as follows:

	0 - 4 weeks	
	Body weight	Feed conversion
6% Crab Meal	598	1.52
3% Crab Meal	589	1.52
0% Crab Meal	560	1.54
	4 - 8 weeks	
5% crab meal	1442	1.85
0% crab meal	1422	1.85
5% herring meal	1446	1.81
0% herring meal	1418	1.89

Up to 4 weeks crab meal improved liveweight gain and feed conversion significantly. From 4-8 weeks it resulted in a small increase in liveweight gain but not in feed conversion. On the other hand, herring meal improved both parameters significantly. This trial shows that 3 or 6% crab meal in the diet improves performances up to four weeks. From four to eight weeks crab meal improves only weight gain whereas herring improves both parameters significantly. The responses are undoubtedly due in part to fish meals having superior energy content to soya and crab meal.

Chang and Waibel (1970) also working in the U.S.A. investigated the effects of including either 5% herring meal or 3% fish solubles in turkey poult rations. Diets were isonitrogenous (28%), though the fish meal diet was somewhat higher in energy content than either the fish solubles or all-vegetable protein (including dehulled soya) diet - 2,083, 2,768, and 2,757 kcal respectively. A comprehensive mineral/vitamin supplement together with methionine were added to all diets. Mean results obtained for the period up to three weeks of age were:-

	Weight	Feed Conversion
5% herring meal diet	463	1.72
3% fish solubles	412	1.73
Basal (all vegetable protein diet)	415	1.78

Growth was significantly improved with the herring meal diet and feed conversion was also better. There was no response in growth to fish solubles, though feed conversion was improved. A further experiment by these workers showed an improvement in growth rate as a result of including 5% herring meal, but no difference in feed conversion:

	Body weight at 3 weeks of age	Feed conversion
5% herring meal	391	1.91
Basal (all vegetable protein) diet	371	1.90

Summary of Results

In table 3 data on the effect of incorporating fish meal in turkey diets on growth and feed conversion are given. Most of the data comes from work by Potter and his group. In much of this work soya was replaced by fish meal plus maize. Consequently response in performance would have reflected both the superior energy content of fish meal as well as any tendency to promote growth.

Growth promotion effects to be explained in terms of U.G.F. or some special characteristics of fish meal can only be assessed in the work of Tuller (1972), Chang and Waibel (1970) and Potter *et al.* (1971). From the results of these workers the following facts emerge:

1. Over the period from 0 to 18 weeks of age fish meal inclusion in the young turkey's diet improved growth by 2.8% and feed conversion by 3.6%.
2. Up to 8 weeks a level of 5% fish meal in the diet appears optimum. From 8 to 18 weeks the optimum level appears to be 3%.

In arriving at the effect of fish meal incorporation in the diet it must be pointed out that replication in half the trials was rather low, with 32 birds or less per treatment. Although in Potter's work his comparison of different levels of fish meal were carried out on far higher numbers per treatment. Many of the treatment combine fish meal with different antibiotics etc. Although in the presence of antibiotics fish meal may still give a response (see later P36) it could well affect the comparisons by interaction, though Potter found no significant interactions. Therefore, data on fish meal in the presence of antibiotics was excluded in this review; hence the low number of birds per treatment.

TABLE 3

Effect on Growth and Feed Conversion of Incorporating Fish Meal in Turkey Diets

Type of Fish Meal	Inclusion Rate %	Period of Growth	Improvement in Liveweight %	Improvement in Feed Conversion %	No. poults per treat-ment	Reference
Herring Meal	5	0–3w	11.6	5.4	32	Chang & Waibel, 1970
Fish solubles	3	0–3w	0.7	2.8	32	" " "
Herring Meal	5	0–3w	5.4	0.6	32	" " "
Menhaden Meal	4	0–8w	1.5	1.5	18	Potter *et al*, 1971a.
" "	8	0–8w	1.0	0.2	18	" "
" "	3	8–18w	1.7	3.4	18	" "
" "	6	0–8w	1.3	0.9	18	" "
" "	9	0–8w	1.3	0	18	" "
Menhaden Meal	5	0–8w	6.3[2]	3.5[2]	18	Potter *et al*, 1971b.
Anchovy "	5	0–8w	11.9[2]	1.4[2]	18	" "
Herring "	5	0–8w	8.0[2]	3.3[2]	18	" "
Peruvian Anchovy	12	0–6w	3.4[1]	3.7[1]	300	Tuller, 1972
" "	6	0–6w	0	4.3[1]	"	" "
" "	2	0–6w	–	–	"	" "
" "	6	6–14w	5.0	24.0	"	" "
" "	2	6–14w	2.5	6.9	"	" "
" "	3	14–18w	2.6	-1.4	"	" "
" "	1.5	14–18w	0.8	0	"	" "
Herring Meal	5	0–8w	16.4[2]	2.7[2]	18	Potter, 1972
Crab Meal	3	0–4w	5.2[3]	1.3[3]	160	Potter & Shelton, 1973
" "	6	0–4w	6.8[3]	1.3[3]	"	" " "
" "	5	0–4w	1.4[3]	0[3]	-	" " "
Herring Meal	5	0–4w	2.0[3]	4.2[3]	-	" " "
Mean	5.0		2.8	3.6		

1. Results expressed relative to those for the 2% diet – a fish meal feed diet was not used from 0–6 weeks.
2. Results excluded because diets not isocaloric and basal diet contained non-marine animal protein, i.e. was not a straight comparison of animal v. vegetable protein diets.
3. Results excluded because diets were not isocaloric.

3.2 TURKEY BREDDER DIETS - HATCHABILITY AND PROGENY GROWTH.

Most of the recent studies of effects of fish product inclusion in turkey breeder diets on hatchability and progeny growth have been carried out by Touchburn and his group at the Agricultural Research and Development Center, Ohio.

In some earlier work Touchburn *et al.* (1972) fed to breeding turkeys a 'complete' diet containing 2.5% meat and bone meal, 2.5% fish meal, 1.5% fish solubles and 2.5% dried whey or a corn/soya bean meal diet. DL methionine was added to the corn/soya diet, and both diets were fortified with a comprehensive mineral/vitamin mixture. The 'complete' diet was slightly lower in both protein and energy content than the corn/soya diet - 16.6% and 1944 kcal (productive energy) for the former and 17.6% and 2034 kcal for the latter respectively. A further comparison of range versus confined (polebarn) rearing was introduced. Superior hatchability for range reared birds (signif. $P < 0.01$) and superior fertility (non-signif.) and hatchability (signif. $P < 0.01$) for birds in confinement was noted for those receiving the 'complete' diet with animal protein:

Rearing Condition	Complete Diet		Corn-Soya Diet	
	Fertility	Hatchability	Fertility	Hatchability
Range reared	75.7	79.8	75.1	71.8 **
Confinement reared	73.2	72.1 **	67.6	68.3 **

(** sign. P<0.01)

Further differences were found in the growth of progeny which were randomly assigned to the 'complete' and corn/soya diets:

Poult Diet	Breeder Diet	
	Complete	Corn-Soya
	Four-week weights (g).	
Complete	437	459 *
Corn-Soya	421	407 **

(*sign. P<0.05)
(**sign. P<0.01)

Poults fed the corn/soya diet grew less rapidly than those fed the complete diet, but the difference reached a highly significant level only for those from parents fed the corn/soya diet. These differences are particularly striking in view of the high protein/energy content of the corn/soya diet.

The effect of animal protein in the breeder diet on growth of progeny was further demonstrated in an experiment where hens fed a corn/soya diet during rearing were then put on various breeder diets and the progeny fed on a corn/soya starter diet:

		Four week weight of progeny (g)
i)	Complete	415
ii)	Corn/soya	384 **
iii)	Corn/soya + 2.5% fish meal + 1.5% fish solubles	407
iv)	Corn/soya + 2.5% dried whey	384 **
v)	Corn/soya + fish + Whey as in (iii) and (iv)	424
vi)	Corn/soya + fish as in (iii) + 5% alfalfa	426

(** sign. $P<0.01$)

Growth was significantly reduced in poults from hens which received either corn/soya or corn/soya plus whey. Though not stated it is assumed that the above diets were designed to be approximately equivalent in nutrient content.

Feeding animal proteins of marine or non-marine origin, Touchburn *et al,* (1972) showed marked responses in breeder turkeys compared with those receiving a corn/soya diet only. In two further experiments in this paper, fish solubles or dried whey were added to either a corn/soya or purified (glucose/cellulose/isolated soya) basal breeder diet and hatchability and progeny growth determined. The poults received a corn/soya diet. The hatchability results were as follows:

Breeder diet Supplement	Hatchability %	
	Corn-soya diet	Purified diet
Fish solubles	55.2	44.1 *
Dried Whey	43.3	35.4
None	49.3	33.3

(* sign. $P<0.05$)

Hatchability was improved when fish solubles were added to either a corn/soya or purified diet, but the increase was only significantly for the latter diet.

The effect of breeder diet on subsequent growth of the progeny are shown in the table below:

Supplements to corn/soya Basal Breeder diet.	Hatchability %	
	With fish sol.	Without fish sol.
None	72.0	68.6
Penicillin (10 mg/kg)	56.8	58.8
Hen faeces (1% dry wt)	72.2	62.0
Penicillin + faeces	62.5	59.5
Mean	65.9	62.2

None of the above differences was statistically significant.

The effect of the same ingredients added to a corn/soyabean meal poult starter diet are shown below:

	4-week weight (g) *	
	With fish sol.	Without fish sol.
None	454	443
Penicillin	515	480
Faeces	445	463
Penicillin + faeces	503	484
Mean	479	468

* = poults produced by hens fed corn/soya diet.

Difference required for significance

$P < 0.05$	28 g.
$P < 0.01$	37 g.

Breeder Diets	Poult Diet 4-Week weight (g) of poults fed :	
	Corn/soya diet	Purified Diet
Corn/soya + fish solubles	492	429
Corn/soya + whey	490	427
Purified diet	428	399
Purified diet + fish solubles	524 **	433
Purified diet + whey	435	398
Corn/soya	505	411

Growth of poults was improved when fish solubles were included in the purified breeder diet but not when a corn/soya breeder diet alone was fed.

This data shows that inclusion of animal protein in a turkey breeder diet gives responses in the form of improved egg hatchability and improved progeny growth. The results with fish solubles do not indicate that the factor in the animal protein giving the response is necessarily in the fish solubles. These responses with the purified diet when fish solubles were added may reflect some nutrient inadequacy. This nutrient may be present in corn/soyabean meal, and is also present in fish solubles in adequate quantities. Touchburn *et al.* point out that whatever factor is present in the animal protein, it can be transferred via the egg to improve growth of the poult. This rules out a direct effect of gut micro-organisms as they cannot be transferred. But is does not rule out the possibility of a metabolite from gut micro-flora being responsible.

A later paper by the same group of workers, Touchburn *et al* (1974), shows a response in growth of poults where the hens received fish solubles (2%) in their breeder diet:

Breeder Diet	Poult Diet			
	Starch + Isolated Soya	Starch + Isolated soya + Fish solubles	Corn / Soya	Corn-Soya + fish solubles
		Growth of poults (g)		
Corn/soya + fish solubles	474	465	529	525
Starch + isolated soya protein	418	443	461	481
Corn/soya	487	465	485	530

This response occurred when the poults subsequently received a corn/soya diet, but not when they received fish solubles or starch and isolated soya.

In this paper Touchburn *et al.* studied in some detail unidentified growth factors in fish solubles. Following the suggestion by Harrison (1972) that fish solubles tend to prevent the growth depressant effect of gut-micro-flora in chicks, and earlier work by Barnett and Bird (1956) (see Touchburn *et al.* 1974) showing that chicks did not respond to fish solubles in a microbiologically clean environment, these aspects were investigated in the trials by Touchburn *et al.* (1974) with the breeding turkey. Relative to a corn-soyabean diet, incorporation of 1% faeces depressed hatchability whereas 1% faeces plus 2% fish solubles increased hatchability as did inclusion of 2% fish solubles alone. Penicillin alone or in combination with either faeces or fish solubles depress hatchability:

Supplements to corn/soya basal breeder diet	Hatchability %
None	68.6
Dried fish solubles (F.S.)	72.0
Penicillin 10 mg/kg (Pen)	58.8
Hen Faeces 1% dry wt (Faec)	62.0
F.S. + Pen	56.8
F.S. + Faec.	72.2
Pen + Faec.	59.5
F.S. + Pen + Faec.	62.5

None of the differences was statistically significant.

The effect of the same ingredients added to a corn/soyabean meal poult starter diet are shown below:

Supplement	4-week weight (g) *
None	443
F.S.	454
Pen.	480
Faec.	463
F.S. + Pen.	515
F.S. + Faec.	445
Pen + Faec.	484
F.S. + Pen. + Faec.	503

* poults produced by hens fed corn/soya diet
Diff. required for significance $P<0.05$ 28 g.
$P<0.01$ 37 g.

Penicillin alone or with fish solubles increased growth. The response to these two supplements appeared to be additive. The single addition of fish solubles or faeces had no significant effect.

Some of the batchability data in the work of Touchburn *et al.* show very varied responses to different levels of inclusion of fish solubles in the diet.

Level of fish solubles in corn-isolated soya diet	Hatchability %
None	61.8
0.25	59.4
0.5	68.4
1.0	61.4
2.0	63.7
4.0	59.2

Difference required for significance

$P < 0.05$	4.1 %
$P < 0.01$	4.8 %

These results (experiment No.4) indicate that hatchability data can be inconsistent and must therefore be interpreted with caution.

The fact that the growth responses resulting from including fish solubles plus penicillin in the diet are additive suggest that if they are modifying gut microfilm different modes of action are involved. Furthermore, the finding that a factor from fish solubles can be transmitted via the egg suggests that more than one factor is involved in the effects on hatchability and growth. A possibility, for example, is that the transmittable factor affects immunilogical status. Raising this status in the young poult may reduce growth depressant action of gut flora (Harrison, 1975).

Inconclusion, it would appear that inclusion of fish solubles in the ration of the breeding turkey will improve hatchability and subsequent early growth of the progeny. However, the responses are variable and there is currently insufficient consistent data to be be able to indicate the extent of the improvement in hatchability and subsequent growth which meight be expected.

4. POSSIBLE EXPLANATIONS OF THE UNIDENTIFIED GROWTH FACTORS IN FISH PRODUCTS

In the many experiments reviewed so far, each one has compared growth of broilers or turkeys fed diets with and without fish meal under a variety of circumstances in different parts of the world. In all these experiments, the fish meal and indeed other feeds used were ascribed a nutritive value, and diets were formulated to be nutritionally equivalent on the basis of these values. Results were variable in some experiments chicks receiving diets containing fish meal performed significantly better than those receiving an all-vegetable protein diet; in other experiments there were no differences. It must be remembered, of course, that a no-difference result indicates that the birds responded as predicted from the nutritive value ascribed; an improvement implies a response greater than predicted. To explain the latter situation, 'unidentified growth factors' (UGF) have been ascribed to fish meal. Certainly, even in the recent experiment outlined above, there is still a significant number which, despite comprehensive balancing of known nutrients including vitamin B_{12} and methionine, suggest that there are still U.G.F.'s in fish meal which promote growth. Numerous explanations of such factors have been put forward these will be reviewed here briefly.

Methods of evaluating unidentified growth factors are still in a state of refinement. Improvements in methodology are outlined in papers by Bhargava and Sunde (1968 and 1969), and Miller and Soares (1972). These papers deal largely with the use of semi-purified diets fortified with comprehensive supplements of trace nutrients, including crystalline amino acids. Although these workers go to some lengths to incorporate all known nutrients, responses to fish meal incorporation are still demonstrated. Performance of the chicks receiving these semi-purified experimental diets suggest that there is still room for considerable improvement before matching performance of birds fed conventional diets (Miller and Soares, 1972).

Most investigations of unidentified growth factors have used conventional diets with or without supplements of the factor they are attempting to investigate (e.g. sulphate, taurine, arsenic). Recent techniques using gnotobiotic (germ free) chicks have led to the suggestion that gut microflora may be involved in the growth promotion effect of fish meal.

Sulphate and Taurine

Dietary sulphate is used in the synthesis of taurine (Martin *et al* 1966), and the same worker showed that methionine enhances taurine synthesis in the liver. Consequently the possible role of sulphate and taurine as unidentified growth factors in fish meal will be discussed together.

The sulphur amino acids, cystine and methionine, constitute about 90% of the total sulphur content of most plants. Thus the availability of sulphate sulphur to poultry fed natural feedingstuffs, particularly corn-soyabean type diets, is limited.

Inorganic sulphur *per se* has been ascribed a role in the metabolism of the chicken (Machlin, 1955). Miraglia *et al.* (1966) and Ross and Harms (1970) observed a growth response in chicks to sulphate added to diets adequate in methionine.

The presence of inorganic sulphate in fish solubles, introduced in the processing, has led to investigation of this nutrient as a possible explanation of the apparent unidentified growth factor in fish product.

Hinton and Harms (1972) found that the improvement in growth of broilers fed a basal diet supplemented with 3% fish solubles could be obtained by substituting 0.2% sodium sulphate for the solubles. Addition of sulphate to the basal diet in this experiment was deficient in methionine. In contrast, when sulphate, methionine or fish solubles were added to corn-soyabean type diets with 20 or 24% crude protein, only the fish solubles gave a significant improvement a very low protein diet (12%) with methionine or sulphate, significant growth responses were obtained from methionine only, despite the fact that the dietary content of sulphur amino acids in the basal diet was calculated to be 0.36%.

In some situations it would appear that sulphate sulphur can supplement the sulphur amino acids. Whilst the sulphate content of fish solubles may in some cases improve growth, e.g. where sulphur amino acids are limiting, sulphate has not yet been shown to fully account for unknown growth factors in fish solubles.

The presence of much higher levels of taurine in fish proteins and its virtual absence in feeds of vegetable origin (Roe and Weston, 1965), coupled with a demonstration of improved growth and feed efficiency in chicks fed diets supplemented with taurine (Martin and Patrick, 1966) led Monson (1969) to investigate taurine as a possible unidentified growth factor in fish meal. Whilst fish meal (5%) incorporation in the basal diet led to a significant improvement in chick growth to four weeks of age, neither 0.05% taurine nor 0.056% sodium sulphate produced any improvement in growth. The basal diet contained 0.88% sulphur amino acids and 0.0035% taurine. With 5% fish meal the taurine level was raised to 0.0204%. This experiment shows that taurine does not account for the unknown growth factors in fish meal.

Arsenic

Synthetically produced organic arsenic compounds such as arsenilic acid are used as dietary growth stimulators in domestic animals. Arsenic is present in fish at higher levels than in land animals, and is present mainly in arseno-organic compounds. To investigate the possible growth stimulating effect of this source of arsenic, Bjornstad *et al.* (1974) recently added arsenic in the form of arsenic containing cod liver hydrolysate. (140 ppm arsenic in dry-matter). This was added (0.36% or 1.8%) to a corn-soyabean basal diet designed to be nutritionally adequate. Further treatments included addition of 50 ppm arsenilic acid and substitution of the soyabean meal with 5% capelin keeping diets isonitrogenous. The latter contributed the same quantity of arsenic (0.25 ppm) to the diet as the arsenic enriched cod liver hydrolysate.

The fish meal improved growth by 4% and feed conversion by 3% (not significant), whereas the arsenic enriched hydrolysate and the arsenilic acid each improved growth by about 1%. The authors reported that the responses to the latter two were too small to conclude that the arsenic content of fish meal contributes towards its growth promoting effects.

Selenium

The need for selenium in poultry rations has been recognised for some time. A recent report by Scott from Cornell University (Scott, 1975), indicates that not only does the chick have a requirement for 0.1 ppm selenium in the diet, but performance may be improved by including rather more up to 0.2 ppm. As selenium (Se) does not become toxic until a level of 5 ppm is reached, the levels indicated by Scott for use in chick diets give a reasonable safety margin. As corn contains 0.075 ppm Se and soya 0.1 ppm (Feedstuffs Yearbook Issue, 20th September 1974), it is likely that corn/soya diets will contain a total Se level below 0.1 ppm. Furthermore the recent report by Scott (above) indicates that the availabilities of Se in corn and soya are 86 and 60% respectively, with 0.065 and 0.06 ppm available Se respectively.

As fish meal contains a relatively high level of Se (approx 2ppm) this is likely to make a significant contribution to a diet in which it is included. Although the availability is not high, Scott (1975) found Se in fish meal to be about 30% available, i.e. 0.6 ppm available Se, fish meal is still likely to contribute significantly to total available Se. On the basis of Scott's data, fish meal has ten times more available Se than soyabean meal or maize. Similar data on Se content of fish meal and its retention have been reported by Miller *et al.* (1972).

This work indicates that the response to fish meal inclusion in corn/soya diets could be due in part to the Se contribution of the fish meal. Of the papers reviewed earlier, only the recent ones by Bjornstad *et al* (1974) and Miller *et al* (1974) appear to have used supplementary Se in their diets. As both groups of workers reported a response to fish meal, it would appear that a response to Se could only account for part, if any, of the responses noted in other similar comparisons.

Gut Microflora

When conventional and germ free (gnotobiotic) chicks were fed balanced diets with and without fish solubles, the conventional chicks grew less well than the germ free chicks without fish solubles (Harrison and Coats, 1969). This work suggested that the microflora in the gut of the chick tend to depress growth and that this growth depression was overcome by incorporation fish solubles in the diet. There is a similarity between this effect and those of antibiotics which is supported by the observation that fish solubles generally produced a thinning of the gut wall (Harrison and Coates, 1972). Antibiotic feeding produces a similar effect almost universally. The thinning of the gut wall is though to permit more efficient utilisation of nutrients.

The work of Touchburn *et al* (1974) described earlier in section 3.1 showed that fish solubles exerted a growth promoting effect on turkey poults fed diets with or without penicillin. Indeed in a number of broiler experiments where responses to fish meal were found, diets fed contained antibiotics (Hartel, 1969; Vogt and Stute 1967 and 1968; Rose-Marie Wegner,. 1970; Day and Dilworth, 1970; Avila and Balloun, 1974).

Therefore it would appear that whilst there may be some similarities in the types of growth response obtained with antibiotics and fish products, the presence of antibiotic does not prevent a growth response from fish products.

Harrison and Coates (1972) went on to show that the growth depression caused by feeding germ free chicks with droppings from conventional chicks was prevented when fish solubles were included in the diet. When autoclaved droppings were fed no depression in growth occurred, indicating that the intestinal microflora are directly responsible for growth rate depression. A bacteria-free filtrate prepared from droppings also resulted in no growth depression when fed, indicating that a non-bacterial component such as a virus is not the factor involved. These results, therefore, show that gut microflora have a direct growth depressant effect on the chick which can be prevented by incorporation of fish solubles in the diet. The response to fish solubles, as indeed with penicillin, was found to be variable. This may be due to varying gut microflora with changes in environment. Recently hatched chicks introduced into a new building tend to have a limited gut microflora, and give little if any response to pencillin. In view of the possible similar mode of action, response to fish solubles would also be expected to be small, if any, in these circumstances. Greater response would be expected therefore in a less clean environment where chicks have been housed previously (Barnett and Bird 1965, Harrison, 1975 - Personal communication). This possible explanation of the unidentified growth factor in fish solubles and perhaps in fish meal also, because of its variable effect, is all the more plausible in view of the variable responses to fish meal in the work reviewed earlier.

Miller and Soares (1972) feeding semi-purified diets with and without fish solubles found that the growth rate of both conventional and germ free chicks was enhanced by including fish solubles in the diet. However a very limited number of birds were used in this part of the work reported and so it cannot be taken to contradict Harrison's findings.

The fact that Touchburn *et al* (1974) demonstrated a response in the growth of turkey poults from a parent fed fish solubles shows that a growth factor can be transferred via the egg. This transferrable factor could not be micro-organisms as such, but perhaps a metabolite. As has been suggested earlier (Page 10.) this transferrable factor may be effective through immunilogical status, this being increased in offspring of fish solubles fed parents. It is also possible that U.G.F.'s involved multiple factors, some which affect growth and others which affect hatchability.

5. INTEGRATING DISCUSSION AND CONCLUSIONS

All the classes of poultry considered in this report (broilers, turkeys, layers, breeder and turkey breeders) show benefits in performance and efficiency of feed utilisition when fish meal is included in their diets. This conclusion is drawn from extensive work carried out in many different countries in the last few years, indicating that fish meal produces a performance response in poultry over and above that predicted by its generally accepted nutritive value.

While the actual factor(s) or characteristic(s) of fish meal responsible for this response have not yet been proven, there is evidence that one or more of the following may be involved:

1. A beneficial effect on gut micro-organisms when fish meal is included in the diet. It appears that by some mode of action not yet understood, gut micro-organisms depresds growth of chickers and turkey poults. Fish meal will reduce this depressant effect.

2. Althoughmuch attention has been paid to the amino acid content of poultry diets, most has been directed towards the sulphur amino acids and lysine. It has been recognised for some time by nutritionists that other essential amino acids are important and may well limit performance when the requirements for the amino acids referred to previously are met- that is, when the requirements for the first and second limiting amino acids are met, the third and then further limiting become first and second limiting and so on. It may be that the overall content of available amino acids in fish meal, and particularly the balance, is superior to that of other feed proteins in terms of meeting the bird's requirement for all essential amino acids.

3. Fish meal contributes oil to the diet which is rich in essential fatty acids. If they supply of essential fatty acids from a diet is limiting performance then the oil from fish meal may make a significant contribution.

4. Energy values used for fish meal may be below its true energy contribution. This could apply particularly to fish meals which have been treated with anti-oxidant.

5. The balance of micronutrients in fish meal may be superior to that in other proteins, especially those of vegetable origin.

In terms of diet formulation, the true value of fish meal in a diet will be above its value predicted by a least cost formulation exercise because of its beneficial effect on feed utilisation. This can be illustrated by the following example:

A Comparison of the Effect of Feeding Diets with and without Fish Meal on the Profitability of Layers

The costings for this exercise are based largely on data in the April 1975 Edition of the National Farmers' Union publication 'Quarterly Egg Production Bulletin'. They are taken to represent costings prevailing in the U.K. for egg producers in March 1975.

Using the data from the survey of world literature it is assumed that the inclusion of 4.2% fish meal in the diet will increase egg production by 4.2% (see table 2). Based on raw material prices in March 1975 a least cost formulation exercise indicated that it would have cost the feed mixing company an extra £0.75 to include 4.2% fish meal in a ton of layers diet. It has been assumed that the egg producer in turn would have to pay an extra £1 per ton for the fish meal diet.

The relative production data (costings based on the above Bulletin) are then as follows:

No eggs / bird (white eggs) / laying period	240
Amount feed fed / bird in laying period	42.5 kg
Cost of feed* / ton	£70.0
Cost of feed* / ton (allowing additional cost of including 4% fish meal see above)	£71.0

(1. based on raw material prices and compounding costs in March - not NFU figure).

	Costs (pence) per bird per laying period	
	With fish meal	Without fish meal
Feed	301.8	297.5
Cost 20 week old pullet	126.0	126.0
Labour	25.4	25.4
Depreciation/maintenance of equipment	25.0	25.0
Miscellaneous (Light, water, medicants etc.)	14.5	14.5
Total	492.7[2]	488.4[2]

On basis that the birds fed fish meal diet will produce 4.2% more eggs, (i.e. 250.1 v 240) the returns will be as follows:

	With fish meal	Without fish meal
Eggs (white eggs sold to packing station at 24p for 12)	500.2	480.0
Bird after lay (1.93 kg at 11p/kg)	21.2	21.2
Total return	521.4	501.2
Total costs	492:7	488.4
Profit	28.7[2]	12.8[2]

(2. excludes interest on capital)

That is, feeding a diet containing 4.2% fish meal costing an additional £1/ton to the producer, the profitability per bird allowing for the additional feed costs would be increased from 12.8p to 28.7p based on costings from the National Farmers Union for April 1975 (Quarterly Egg Production Bulletin).

At that time profitability was low for the egg producer. In better times he would expect several times this profit level.

When profitability is high an extra 16p profit per bird is very beneficial. When profitability is low, such an increase assumes even greater importance.

Clearly fish meal has an important role to play in poultry diets. Including fish meal in these diets will give the best cost formulation if not the least cost, in that the benefits resulting should more than cover the cost of including fish meal.

5. LITERATURE REFERENCES

AITKEN, J.R., BIELY, J., NIKOLAICZUK, N., ROBBLEE, A.R., SLINGER, S.J. (1971). Comparison of Laying Rations with and without Animal Protein at the Canadian Random Sample Egg Production Test. British Poultry Science. *10*, 247-253.

ANDERSON, J.O. and *WARNICK, R.E.* (1972). Nutritive Value of Three Animal Protein Supplements for Chicks. Feedstuffs. 24.4.72., page 28.

AVILA, E and *BALLOUN, S.L.* (1974). Effects of Anchovy Fish Meal in Broiler Diets. Poultry Science. *53*, 1372-1379.

BEARSE, E. (1971). Fish Meals in Rations of White Leghorn Laying and Breeding Chickens. Feedstuffs. *43*. (13), P.30.

BHARCAVA, K.K. and *SUNDE, M.L.* (1968). A Short Time Chick Assay for Unidentified Growth Factors. Poultry Science. *48*. (2), 694-7.

BIELY, J. and *WOOD, C.W.* (1971). A Comparison of Rations fed to Laying Birds in Cages. Poultry Science. *50*, 969-972.

BJORNSTAD, J., OPSTVEDT, J., and *LUNDE, G.* (1974). Unidentified Growth Factors in Fish Meal. Experiments with Organic Arsenic Compounds in Broiler Diets. British Journal of Nutrition. *15*, 481-487.

BLACK, D.J.G., JENNINGS, R.C., MORRIS, T.R. and *PALGROVE, J.A.* (1954). (A depressant effect of a white fish meal on hatchability.) Proceeding 10th World Poultry Congress, *10*: 121-125.

BONOMI, A. and *BIANCHI, M.* (1972). The Influence of Rations with different Animal Protein Levels on the Health and Productivity of Laying Hens on Deep Litter. Institute of Special Animal Husbandry University of Turin Faculty of Agric. Science. 245-260.

CHANG, C.H. and *WAIBEL, P.E.* (1970). Efficiency of Zinc Bacitracin and Sources of Unidentified Growth Factors with Corn-Soyabean Meal Type Diet for Turkey Poults. Poultry Science. *49*, 733-743.

COLES, R. (1956). Observations on the occasional depressing influence of Fish Meal on the hatchability of hens' eggs. Journal Agricultural Science (Cambs), *47* 354-362.

COOPER, J.B. and *HUGHES, B.L.*, (1974). Vegetable diet with or without Fish Meal and Hatchability of Chicken Eggs. Poultry Science. *53*, 1849-1852.

COWPER, J.R. (1972). The Value of Fish Meal in Laying Diets under Practical Conditions. Poultry Industry. Feb. 1972.

COWPER, J.R. (1974). Further Research on the Value of Fishmeal. Journal of Flour and Animal Feed Milling. July, 1974, 1-4.

DAMRON, N.L. EBERST, D.P., and *HARMS, R.H.* (1971) The Influence of Partially Delactosed Whey, Fish Meal and Supplemental Biotin in Broiler diets. Poultry Science, *50*, (6), 1768 and 1771.

DAY, E.J. and *DILWORTH, B.C.* (1965). Unidentified Factor Sources for Broiler Rations. Feedstuffs. *37*, (31), 74.

DAY, E.J. and *DILWORTH, B.C.* (1970). Comparison of Different Types of Fish Meal in Practical Broiler Diets. Feedstuffs, *42*, (3), 22.

DE GROOTE, G. (1973). Research on complete Fish Meal replacement by Soya Cake in variable Energetic Content Rations for Broilers. Revue de l'Agriculture, *4*, 1-8.

HARRISON, G.F. (1972). Unknown Growth Factors in Fish Solubles. I.A.F.M.M. News Summary No. 34, 81-89.

HARRISON, G.F. (1975). Personal Communication.

HARRISON, C.F. and *COATES, M.E.* (1969). The Effect of Gut Flora on the Growth Response of the Chick to Fish Solubles. Proceedings of the Nutrition Society. *28*. 704.

HARRISON, G.F. and *COATES, M.E.* (1972). Inter-relationship between the Growth Promoting Effect of Fish Solubles and the Gut Flora of the Chick. British Journal of Nutrition. *28*, 213-221.

HARTEL, H. (1968). Testing Varying Levels of Fishmeal in Broiler Rations. Archiv. für geflugelkunde. *32*, 13-29.

HARTEL, H., EBERSDOBLER, H., and *ZUCKER, H.* (1968). The Effect of Methionine Supplementation in Chick rearing rations with different protein carriers and protein concentrations. Archives für geflugelkunde. *33*, (5), 332-343.

HERSTAD, O. (1973). Herring Meal and Methionine Supplementation in Broiler Feed. Meldinger Fra Norges Landbrukshogskole. *52*, (16), 1-23.

HERSTAD, O. (1974). Fish Meal, Methionine and Vitamin B12 in Chick Rations. Proceedings of the 3rd. European Symposium on Use of Fish Meal in Animal Feeding.

HINTON, C.F. and *HARMS, R.H.* (1972). Evidence for Sulphate as an Unidentified Growth Factor in Fish Solubles. Poultry Science. *51*, 701-703.

LINDSTROM, R.G., PETERSEN, C.F., WIESE, A.C. and *MORE, P.R.* (1949). (Effect on hatchability of fish meal fed to hens deficient in the unidentified hatchability factor.) Poultry Science. *28*: 552-555.

MACULIN, L.J. (1965). Studies on the Growth Response in the Chicken from the Addition of Sulphate to a Low-Sulohur Diet. Poultry Science. *34*, 1209.

MARCH, B.E., BIELY, J. and *TARR, H.L.A.* (1967). The Effect of Fish Meal supplementation of Chicken Breeder Rations on Hatchability. Poultry Science. *46*, 532-1536.

MARTIN, R.S., CHUBB, L.G., FOX, S., JENNINGS, R.C. and *MORRIS, T.R.* (1960). (The effect of white fish meal on the hatchability of hens' eggs.) British Poultry Science. *1*: 135–143.

MARTIN, W.G. (1972). Sulphate Metabolism and Taurine Synthesis in the Chick. Poultry Science, *51*, 608-612.

MARTIN, W.G.R., MIRAGILIA, R.J., SPAETH, D.G. and *PATRICK, H.* (1966). Synthesis of Taurine from Sulphate by the Chick. Proceedings of the Society of Experimental Biological Medicine. *122*, 841-844.

MARTIN, W. and *PATRICK, H.* (1966). The Incorporation of S350 into bile of chicks. Proceedings of the Society of Experimental Biology and Medicine, *121*, 414.

MILLER, D., BIDDLE, G.N., BAUERSFIELD, P.E., and *CUPPET, S.L.* (1974). Soyabean Meal diets supplemented with sulphate, methionine and fishery products. Poultry Science, 53, 226-234.

MILLER, D., SOARES J.H., BAUERSFIELD, P.E. and *CUPPET, S.L.* (1972). Comparative selenium retention by chicks fed sodium selenite, selenomethionine, fish meal and fish solubles. Poultry Science, *51*, 1669.

MILLER, D and *SOARES, J.H.* (1972). A Study of the Method Methodology for Assaying Unidentified Growth Factor in Fish Meal and Fish Solubles. Poultry Science, *51*, 1288-1291.

MONSON, W.J. (1969). Evidence that Taurine may be One of the Elusive Unidentified Factors. Poultry Science. *48*, (6), 2069-2074.

OPSTVEDT, J. and *GJEFSEN, T.* (1975. Unidentified Growth Factors in Fish Meal: Effects of low levels of Fish Meal in Diets for Breeder Broiler Hens. Poultry Science in press.

POTTER, L.M. (1972). Effects of Erythromycin, Fermato-500, Herring Fish Meal and Taurine in Diets of Young Turkeys. Poultry Science. *51*, 325-331.

POTTER, L.M. LEIGHTON, A.T. and *HOWES, C.E.* (1971b). The Effects of Fish Meal Methionin and Different Cereal Grains in Diets of Young turkeys. Poultry Sciene *50*, (4), 1100-1108.

POTTER, L.M. and *SHELTON, J,R.* (1973). Evaluation of Crab Meal as a Dietary Ingredient for Young Turkeys. British Poultry Science, *14*, 257-261.

POTTER, L.M. SHELTON, J.R. and *KELLY, M.* (1971 a). Effects of Zinc Bacitracin, Dried Bakery Product and Different Fish Meals in Diets of Young Turkeys. Poultry Science, *50*, (4), 1109-1115.

ROE, P.A. and *WESTON, M.O.* (1965). Potential Significance of Free Taurine in the Diet. Nature. *205*, 287. Proceedings of the Society of Experimental Biology and Medicine. *121*, 414.

ROSS, E. and *HARMS, R.H.* (1970). The Response of Chicks to Sodium Sulphate Supplementation of a Corn-Soya Diet. Poultry Science. *49*, 1605-1610.

SCOTT, M.L. (1975). Feed Manufacturers Conference, Nottingham. Proceedings in Press.

SOLBERG, J. (1971). Effects with Layers of Different Levels of Protein, Herring Meal, Methionine, and Lysine in Their Diets. Archives für geflügelkunde. *36*, (4), 164-169.

TOUCHBURN, S.P., CHAMBERLIN, V.D. and *NABER, E.C.* (1972). Unidentified Factors in Turkey Nutrition affecting Hatchability and Progeny Growth. Poultry Science. *51*, 96-103.

TOUCHBURN, S.P. SILVA, R.D.M., and *NABER, E.C.* (1974). Further Evidence for an Unidentified Nutrient in Progeny Growth of Turkeys and Japanese Quail. Poultry Science. *53*, 1745-1758.

TULLER, R. (1972). Replacement of Fishmeal in Feeding Rations for Fattening Turkeys by Soyabean Meal. Archives für geflügelkunde. *36*, 166-170.

VOGT, H. (1968). Investiongations of Fish Meal and Plant Protein III Laying Hen Trials. Archives für geflügelkunde. *32*, 225-241.

VOGT, H. and *STUTE, K.* (1967). Trials on the Complete Substitution of Fish Meal by Vegetable Protein Carriers. II. With and Without Dried Whey. Archives für geflügelkunde. *32*, 30-44.

ROSE-MARIE WEGNER (1970). Chicken Fattening Trials with and without Fish Meal and with and without Salt Compensation in the Ration. Archieves für geflügelkunde. *34*, (4), 135-139.

ROSE-MARIE WEGNER (1968). Trials with Broiler Rations in Which Animal Protein has been substituted by Vegetable Protein. Archiv. für geflügelkunde. *32*, (4), 242-253.

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