Effect of Fishmeal Supplementation on Body Weight Gain of White Leghorn Starter Chicks in Eritrea

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Abstract

Two 8-week feeding trials were carried out to investigate the effect of supplementing an inadequate commercial diet available in Eritrea with fishmeal produced locally by sun-drying and grinding on the body weight gain of White Leghorn chicks. The commercial diet consisted of a mixture of sorghum, wheat middlings, maize, meat and bone meal, and salt to make 50, 34, 10, 5, and 1 % of the diet by weight. In the first trial, 200 chicks were divided into 2 groups of 100 each. One group was fed on the control diet (C1), which consisted of the commercial diet while the other group was fed on the commercial diet supplemented with fishmeal to make 13 % of the diet by weight (FM1). The CP, CF, lysine, methionine + cystine, Ca and P content in % and ME in MJ/kg of C1 was 13.76, 3.96, 0.36, 0.48, 0.05, 0.5 % and 11.81, respectively. After supplementation with 13 % fishmeal, the CP, CF, lysine, methionine + cystine, Ca, and P content in % and ME in MJ/kg was 19.33, 3.45, 0.74, 0.65, 1.25, 0.75 and 11.70. In the second trial, the same experiment was repeated with a total of 40 chicks divided into 2 pens of 20 each with each pen fed either the commercial diet (C2) or the fishmeal supplemented diet (FM2). The composition of C2 was 15.23, 4.49, 0.40, 0.52, 0.08, 0.60 % and 11.81 MJ/kg of CP, CF, lysine, methionine + cystine, Ca and P and ME, respectively. Supplementation of 13 % fishmeal by weight resulted in FM2 having CP, CF, lysine, methionine + cystine, Ca, P % and ME (MJl/kg) of 20.31, 3.91, 0.77, 0.68, 1.28, 0.86 and 11.68, respectively. Feed intake per pen was measured daily. Body weights of representative samples of chicks were taken weekly.

The total feed consumption per chick fed on FM1 was 1919 g for the 8-week trial period, 162g higher than chicks fed on C1. Chicks fed on FM1 attained a significantly higher ($P<0.001$) body weight of 766 g compared to 397g for the chicks fed on C1 at the end of trial 1. Similarly, chicks fed on FM2 had a significantly higher ($P < 0.001$) feed intake of 1655 g compared to chicks fed on C2 with a total feed intake of 1262 g per chick. Chicks fed on FM2 attained a mean weight of 616.9 g compared to 244.8 g for chicks fed on C2. Fishmeal supplementation reduced mortality and increased feed conversion ratio in both trials.

Keywords: body weight gain, chicks, feed intake, fishmeal

Introduction

Fishmeal is a high quality animal feed used to provide a good balance of essential amino acids, energy, vitamins, minerals and trace elements for poultry, pigs and ruminants (FAO 1986; Bimbo and Crowther, 1992; O'Connor et al., 1993). However, the high cost of imported fishmeal (Amadei, 1998; Nwokoro and Olumide, 1996) has increased the need to explore locally available sources of fishmeal either from shrimp by-catch or small pelagic fish (Tuitoek and Ayangbile, 1994). Fishmeals locally produced mostly through sun-drying and grinding have been shown to have a comparable nutritive value to imported fishmeals (Lim et al., 1989; Eid et al., 1992; Steiner-Asiedu et al., 1993; Farkhoy et

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al., 1995). Promising results have been obtained from trials carried out on poultry and pigs using locally prepared fishmeals (Tuitoek, 1992; Bouzouaia and Rekhis, 1994; Tuitoek and Ayangbile, 1994; Nwokoro and Olumide, 1996). Shortage of high quality protein supplements is a major constraint to the development of the poultry industry in Eritrea. At the moment, there is no diet in Eritrea that is being prepared to meet the requirements of starter or grower chicks. As a result, poultry keepers are forced to depend on a diet prepared for layers to feed chicks either alone or by supplementing it with household leftovers or boiled fish waste. Eritrea has a big potential to meet supplementary protein needs of its poultry and livestock from the utilisation of small pelagic fish, shrimp by-catch fish and fish waste.

The objective of this experiment was to examine the effect on body weight gain of supplementing locally produced fishmeal to the commercial diet of starter White Leghorn chicks.

Materials and Methods

Trial 1

Two hundred day-old unsexed White Leghorn chicks were fed on a commercial diet (C1) for seven days. On the eighth day the chicks were allocated into 2 pens of 100 each. The chicks were fed either a commercial diet available in Eritrea as a control diet (C1), or the commercial diet supplemented with fishmeal to make 13 % of the diet by weight (FM1).

The experimental diets were fed for 8 weeks when the trials were terminated. Throughout that period the chicks had access to water and feed ad libitum. All the chicks were kept in one deep litter house with the two pens partitioned by wooden fences covered by plastic polythene sheets. Extra heat was provided by 150W light bulbs. Throughout the experimental period, feed intake per pen was measured daily.

Table 1: Composition of diets used in Trials 1 and 2 (%)

Item	C1	FM1	C2	FM2
Sorghum	50	43.5	50	43.5
Wheat middling	34	29.6	34	29.6
Maize	10	8.7	10	8.7
Meat and bone meal	5	4.4	5	4.4
Fishmeal	-	13	-	13
Salt	1	0.9	1	0.9
Percent DM 'as fed basis'	90.85	90.80	91.10	91.05
Crude protein	13.76	19.33	15.23	20.61
Crude fibre	3.96	3.45	4.49	3.91
Fat	3.05	3.50	3.28	3.69
Calcium	0.05	1.25	0.08	1.28
Phosphorus (P)	0.50	0.75	0.60	0.86
Available P (calculated)	0.37	0.65	0.44	0.75
ME, MJ/kg (calculated anal ysis)	11.81	11.68	11.81	11.68
Arginine	0.64	0.87	0.68	0.90
Glycine + serine	1.19	1.71	1.22	1.75
Histidine	0.32	0.41	0.34	0.43
Isoleucine	0.56	0.79	0.61	0.83
Leucine	1.50	1.80	1.60	1.86
Lysine	0.36	0.74	0.4	0.77
Methionine	0.22	0.36	0.24	0.38
Methionine + cystine	0.48	0.65	0.52	0.68
Phenylalanine	0.69	0.88	0.73	0.92
Phenylalanine + tyrosine	1.20	1.58	1.26	1.64
Threonine	0.43	0.61	0.44	0.62
Tryptophan	0.14	0.22	0.15	0.17
Valine	0.68	0.96	0.73	1.00

C1 = control diet in Trial 1; FM1 = fishmeal supplemented diet in Trial 1
C2 = control diet in Trial 2; FM2 = fishmeal supplemented diet in Trial 2

The ingredients of C1 were sorghum, wheat middlings, maize, meat and bone meal and salt making 50, 34, 10, 5 and 1 %, respectively, by weight. The fishmeal-supplemented diet (FM1) was composed of sorghum, wheat middlings, maize, meat and bone meal, fishmeal and salt making 43.5, 29.6, 8.7, 4.4, 13.0 and 0.9 %, respectively, by weight as shown in Table I.

Feed conversion was determined by pen for total feed consumed divided by the total terminal average weight for that pen, adjusted for mortality. Representative samples of chicks were weighed weekly from each pen.

Trial 2

A similar trial was repeated using 40 day-old White Leghorn chicks that were fed on the commercial (C2) diet for five days. On the sixth day the chicks were allocated to 2 pens of 20 each and the experiment was conducted for 59 days with a control diet (C2) and a fishmeal supplemented diet (FM2) under similar conditions to Trial 1. The ingredients of C1 and FM2 were the same as in Trial 1.

Table 2: Average daily feed intake (g) of chicks fed different diets in Trial 1 and 2

Age (weeks)	C1	FM1	C2	FM2	SEM	P value
2	9.41^{a}	10.60^{a*}	16.55^{a}	17.00^{a}	3.79	0.081
3	17.29^{a}	20.89^{a}	17.66^{a}	24.84^{b}	2.30	0.0053
4	25.19^{a}	28.49^{a}	16.70^{b}	27.84^{a}	2.50	0.001
5	30.79^{b}	33.49^{a}	18.89^{c}	28.39^{b}	1.16	<0.001
6	40.13^{a}	39.24^{a}	26.24^{c}	31.74^{b}	2.57	<0.001
7	41.57^{a}	42.81^{a}	28.60^{b}	37.47^{a}	2.83	<0.001
8	43.13^{ab}	47.76^{a}	36.00^{b}	44.25^{a}	3.18	0.008
9	43.54^{b}	50.91^{a}	35.69^{c}	44.21^{b}	2.24	<0.001

^{abc}Means in the same row not sharing a common superscript are significantly different (P<0.05)

*Number of replicates is 7 in each observation.

SEM = Standard error of the mean

Chemical analysis

Samples of the two diets were collected at regular intervals. The contents of crude protein (Kjeldahl-N x 6.25), crude fat (HCl-ether extract), crude fibre, ash, calcium and phosphorus were determined according to standard procedures described by AOAC (Association of Official Analytical Chemists) (1990). Amino acid composition was determined according to OJEC (1998). Tryptophan was determined according to OJEC (2000).

Statistical analysis

Both trials were designed according to completely randomized design. The pen was the experimental unit. Body weights and feed intakes were analyzed using the GLM procedure of the SAS Institute Inc (1990). Results were presented as the least square means (LSMEANS) of the pen in each treatment, and variance of the data was presented as standard error of the means (SEM).

Results

Analysis of rations

The chemical analysis of C1 resulted in the ration having CP, CF, lysine and methionine + cystine, Ca and P of 13.76, 3.96, 0.36, 0.48 %, 0.05 and 0.50 %, respectively, on dry matter basis. The calculated ME was 11.81 MJ/kg. The respective components for FM1 were 19.33, 3.45, 0.74, 0.65, 1.25 and 0.75. The calculated ME for FM1 was 11.70 MJ/kg. C2 had a content of 15.23, 4.49, 0.40, 0.52, 0.08, and 0.60 % of CP, CF, lysine, methionine + cystine, Ca and P, respectively. The calculated ME was 11.81 MJ/kg. The respective components for FM2 were 20.31, 3.91, 0.77, 0.68, 1.28 and 0.86. FM2 had a calculated ME of 11.68 MJ/kg.

Feed intake

The daily feed intake per chick for the 8 weeks of each trial is shown in Table 2. Feed intake was consistently higher for the fishmeal-supplemented groups than for the control. At the end of Trial 1, the total feed intake per chick was 19 g for the chicks fed FM1 while it was 1757 g for the group fed on C1. The total feed intake per chick at the end of Trial 2 was 1655.4 for the fishmeal-supplemented group while it was 1261.6 for the control group.

Chicks in Trial 1 as a whole had a higher feed intake than chicks in Trial 2.

Body weight gain

The chicks supplemented with fishmeal attained a higher (P<0.001) weight of 766 g at the end of Trial 1 while the chicks in the control group weighed an average of 397 g. In Trial 2, the chicks fed the fishmeal-supplemented diet attained a higher (P<0.001) weight of 616.9 g at the end of the trial while the control group weighed an average of 244.8 g. Both experiments showed similar results in that chicks supplemented with fishmeal grew faster than the unsupplemented groups.

The feed consumption and body weight gain of the fishmeal supplemented groups closely agreed with the average genetic potential of mmature Leghorn-type chickens estimated by NRC (1994), while chicks fed the control diets had significantly (P<0.001) lower feed consumption and body weight gain.

During the first weeks of the trials the weight of chicks was being taken without distinguishing between males and females. As it became possible to distinguish between the sexes, weights were recorded for both sexes. In Trial 1, the final weight of males and females for chicks fed on C1 was 418.3 and 375 g, respectively. The corresponding weights for chicks fed on FM1 were 844 for males and 690 g for females. In Trial 2, the mean final weight of males and females fed on C2 was 221 and 259 g, respectively. The corresponding weights for the chicks fed on FM2 were 656.3 g for males and 577.5 g for females.

Table 3: Average body weights of chicks in Trial 1 and 2

Age (weeks)	C1	FM1	C2	FM2	SEM	P value
1	48.7^{a} (6)	48.6^{a} (6)*	41.4^{a} (3)	38.4^{a} (2)	2.61	0.0245
2	57.3^{b} (6)	82.3^{a} (6)	47.8^{c} (4)	61.7^{b} (4)	2.59	<0.0001
3	79.6^{bc} (8)	135.0^{a} (8)	58.7^{c} (2)	100.5^{b} (2)	9.02	<0.0001
4	125.4^{b} (10)	212.6^{a} (10)	72.4^{c} (2)	140.9^{b} (4)	11.95	<0.0001
5	175.7^{b} (10)	328.0^{a} (10)	83.9^{c} (2)	205.3^{b} (4)	22.74	<0.0001
6	181.0^{bc} (10)	431.4^{a} (10)	90.1^{c} (2)	236.8^{b} (4)	26.22	<0.0001
7	-	-	130.8^{b} (2)	306.6^{a} (8)	48.42	0.0018
8	281.7^{b} (10)	597.3^{a} (10)	147.1^{b} (2)	402.6^{c} (8)	48.84	<0.0001
9	396.7^{b} (6)	766.0^{a} (10)	192.3^{d} (4)	519.9^{c} (8)	61.11	<0.0001
10	-	-	243.7^{b} (5)	616.9^{a} (8)	68.44	<0.0001

^{abcd}Means in the same row not sharing a common superscript are significantly different (P<0.05)

*Numbers in bracket are sample sizes

SEM = Standard error of the mean

Mortality

In Trial 1 the mortality rate for chicks fed on C1 was 18 % while it was 9 % for the chicks fed on FM1. During Trial 2, mortality for the chicks fed on C2 was much higher at 40 % while it was 10 % for the chicks fed on FM2.

Discussion

Inadequacies of the control diets

The control diets, C1 and C2, were not adequate for starter chicks because of a low CP content with a severe amino acid imbalance, a low Ca content and a high CF content.

The CP content of the control diets, 13.76 and 15.23 %, for C1 and C2, respectively, was much lower than the recommended 18-20 % for starter chicks. This low content of crude protein could have been one cause for the reduced feed intakes of the chicks fed the control diets compared to the fishmeal supplemented ones. Various studies have shown similar results. Leeson and Summers (1979) obtained a feed intake of 1534 g in chicks fed a step-up protein of 12 % CP at 8 weeks of age while the chicks receiving the control diet of 18 % had a feed intake of 1891 g. Chicks in the step-up protein diet attained a body weight of 432 g compared to 633 g for the chicks fed the control diet at 8 weeks of age. Similar results were obtained in the present study. Lee et al. (1971) reported that the use of protein-deficient diets during the growing period, or from one day of age to have apparently very similar results to those of restricted feeding.

In the present study, the control diets (C1 and C2) were not only short in CP in absolute terms, but also highly imbalanced in amino acid content. This could have been another cause for the depression in feed intake of the chicks fed the control diets. Fisher et al. (1960) fed incomplete amino acid mixtures to chicks and found that the chick was as sensitive to amino acid imbalance as the growing rat. The adverse effects of the imbalance were manifested in a reduction in feed intake, which also reduced intake of the limiting amino acids, leading to reduced growth. The control diets in the present study provided inadequate levels of the essential amino acids: lysine, methionine + cystine, threonine, tryptophan and isoleucine as can be seen in Table I. Kwakkel et al. (1991) found that a low-lysine diet (4.0 g/kg of digestible lysine) in the starter phase (0-6 weeks of age) resulted in a 44.3 % depression in total feed intake compared to a control diet with a digestible lysine of 8.5 g/kg. The control diets in the present study had 3.6 and 4.0 g/kg lysine content in C1 and C2, respectively with the digestible lysine expected to be slightly lower. The depression in feed intake for C1 was 9.22 % while it was 31.2 % for C2 compared to FM1 and FM2, respectively. Singsen et al. (1965) fed broiler breeder pullets a diet with 0.57 % lysine and 20 % crude protein from 0 to 8 weeks of age and one with 0.47 % lysine and 16 % crude protein from 8 to 21 weeks of age. They reported that the live weight of pullets at 21 weeks of age was progressively reduced when deficient diets were fed from one day of age for increasing periods. The maximum delay in maturity followed the feeding of the deficient diets from 0 to 12 weeks of age. At 4 weeks of age, chicks started on the lysine-deficient ration had an average body weight approximately one half that of the chicks fed the normal ration, and at 8 weeks it was approximately 60 percent. In the present study, the lysine level was even lower at 0.36 % and 0.4 % and the CP was much lower, at 13.76 % and 15.23 % for C1 and C2, respectively. The results were even more pronounced for the group fed on C2 and similar for the group fed on C1 to that reported by Singsen et al. (1965).

Another imbalance observed in the control diets was between leucine, isoleucine, and valine. Sorghum, which constituted 50 % of the control diets, contains a disproportionate quantity of these amino acids. It contains a relatively high amount of leucine compared to isoleucine and valine. Excess leucine depresses the utilization of the other two branched-chain amino acids, isoleucine and valine (D'Mello, 1992). The adverse effect of excess leucine can be corrected by simultaneous supplementation of isoleucine and valine. The control diets contained excess leucine, while they were adequate in isoleucine and valine (Table I). The leucine level was 1.5 and 1.6 % in C1 and C2, respectively. The requirement is only 1.1 % (NRC 1994). The levels of isoleucine at 0.56 and 0.61 % and valine at 0.68 and 0.73 % for C1 and and C2, respectively, fulfilled the NRC, (1994) recommendation for starter Leghorn-type chicks of 0.60 and 0.62 % for isoleucine and valine, respectively. D'Mello, (1974) showed that a diet supplemented with a small excess of leucine depressed chick growth, which was only partially alleviated with valine supplements.

The calculated estimate of the calcium content was 0.58 %, but the actual content of calcium as determined by laboratory analysis was only 0.05 % for C1 and 0.08 % for C2, respectively. The reason for this could be that the diets did not contain 5 % meat and bone meal as claimed or that there was a failure to mix the ingredients thoroughly. These levels were less than a tenth of the 0.9 % calcium recommended by NRC, (1994) and this alone could have imposed a severe constraint on the growth of chicks even if all the other nutrient requirements were met. The inhibition in growth and higher mortality observed in both the control groups could partly be due to severe Ca deficiency. Ca or P deficiency results in an inhibition of growth, a loss of weight, and reduced or lost appetite before characteristic signs in the bone system become apparent (McDowell, 1992).

Dietary calcium and phosphorus levels have been shown to be important nutrient factors in the expression of a cartilage abnormality, tibial dyschondroplasia, in young chicks (Edwards and Veltmann, 1983). The authors found incidences of 17, 26, and 39 % of tibial dyschondroplasia when the chicks received diets containing calcium and non-phytin phosphorus of 0.70 and 0.35, 0.63 and 0.55, and 0.80 and 0.75, respectively. The incidence of tibial dyschondroplasia was highest when the chicks received diets containing high phosphorus and low calcium rations. The Ca content of 0.05 and 0.08 % for C1 and C2, respectively, in the present study was even much lower than the levels used by Edwards and Veltmann (1983), while the non-phytine P of 0.37 and 0.44 % for C1 and C2, respectively, was similar. Therefore, even though the incidence of tibial dyschondroplasia was not actually determined during the period of the study, it could have affected the chicks fed on the control diets.

The control diets contained high amounts of CF, which came mainly from the high content of wheat middlings in the diets. C1 and C2 had CF levels of 3.96 and 4.49 %, respectively. These levels exceeded the levels of 2.5-2.8 % recommended for starter chicks (Leeson and Summers, 1997). The ME content of the control diets was adequate but the high CF content could have hampered the ability of the chicks to utilise the diets. C2 had a higher protein content (15.23 %) compared to C1 (13.76 %) which also resulted in improvement of the amino acid levels as shown in Table I. However, this improvement in protein content failed to result in improved growth of the chicks fed C2 compared to chicks fed on C1. The diets were assumed to be the same but the higher CP and CF levels obtained after laboratory analysis for C2 compared to C1 suggest that C2 must have contained more wheat middlings than the claimed 34 % of the diet. Wheat middlings contain more CP and CF than maize and sorghum, which were the other ingredients. The increase in CP could not have come from a higher level of meat and bone meal because the lower than expected amount of Ca obtained by analysis indicated that the diets actually contained less than the claimed 5 % of meat and bone meal. Even though the growth of chicks fed FM2 diet was significantly ($P < 0.001$) higher than the C1 fed chicks, it was lower than the growth of chicks fed FM1 diet. Longstaff and McNab (1991) investigated the inhibitory effects of hull polysaccarides on the digestion of amino acids, starch and lipid and on digestive enzyme activities in young chicks and found that a diet with tannin-free hulls lowered slightly the digestion of amino acids, starch and lipid compared with the control diet (without hulls). The authors believed this effect to be due to inhibition of digestive enzymes, possibly through their absorption into the hulls because in their study trypsin and lipase digesta activities were depressed by hull polysaccharides. Bailey et al. (1974) found that food and protein digestion in rats were depressed in direct proportion to the amount of hulls incorporated in the diet. The authors suggested that the higher amounts of hull created excessive bulk, which trapped protein and prevented enzyme-substrate contact.

Effect of fishmeal supplementation

Supplementing with fishmeal increased the protein content to 19.33 % and 20.61 % for FM1 and FM2 diets, respectively, which is within the recommended level. The amino acid balance was improved as well. The lysine level increased from 0.36 and 0.40 in C1 and C2 to 0.74 and 0.77 % in FM1 and FM2, respectively, while the methionine + cystine level increased from 0.48 and 0.52 % for C1 and C2 diets to 0.65 and 0.68 %, respectively. The methionine + cystine level of the supplemented diets fulfilled the NRC (1994) recommendation of 0.62 %. The lysine level was lower than the recommended 0.85 %, but it came close enough to a range where an increase in feed intake could compensate for most of the deficiency. The increase in CP content together with the improved amino acid balance resulted in weekly feed intake of the FM supplemented groups closely agreeing with the NRC (1994) estimations of the feed intake of starter and grower Leghorn-type chicks. Body weight gain of the fishmeal-supplemented groups followed the trend of the feed intake and closely resembled the average genetic potential predicted by NRC (1994) and even exceeded the predictions during the final week of the FM1.

The reason for this could be that the addition of fishmeal also increased the fat content of the diet from 3.05 % in C1 to 3.50 % in FM1 and this could have resulted in a higher energy diet even though the calculated ME value is lower for FM1 than for C1.

The supplementation of fishmeal to the control diets could also have lessened the adverse effect of excess leucine on growth of chicks. The levels of leucine, isoleucine and valine rose by 20, 41, and 41 % respectively in FM1 from C1 while the respective figures for FM2 from C2 were 16.3, 36.1, and 37 %. Even though the leucine level also increased, the proportional increase of both isoleucine and valine was greater after supplementation with fishmeal and this could have mitigated the adverse effects of the excess leucine.

Fishmeal supplementation increased the Ca content from 0.05 and 0.08 % to 1.25 and 1.28 % in FM1 and FM2, respectively, exceeding the NRC (1994) recommendation of 0.90 %. The CF content was also lowered from 3.96 and 4.49 % in C1 and C2, respectively, to 3.45 and 3.91 %, respectively, in FM1 and FM2.

Economic considerations

Fishmeal is an expensive protein supplement. As the growth rates of the fishmeal supplemented chicks indicated, however, it more than compensated for its cost. Feed cost increased with fishmeal supplementation. However, the cost per unit weight gain was lower with the fishmeal-supplemented diets than with the control as shown in Table 4.

Table 4: Effect of fishmeal supplementation to a commercial diet in Eritrea on the erformance of White Leghorn chicks.

	FM1	C1	FM2	C2	SEM	P value
Initial weight, g[1]	48.6^{a} (6)	48.8^{a} (6)	41.4^{a} (3)	38.4^{a} (2)	2.61	0.0245
Final weight, g	766^{b} (10)	397^{a} (12)	616.9^{b} (8)	244.8 ^{a} (8)	61.11	<0.001
Weight gain, g	716.6	348.2	575.4	206.4	-	-
Total feed consumed, g	1919	1757	1655	1262	-	-
Feed/gain contrasts	2.68	5.05	2.88	6.11	-	-
Feed cost (nakfa)[2] /100 g gain	0.47	0.71	0.50	0.78	-	-

[1]Numbers in bracket are sample sizes

[ab]Means in the same row not sharing a common superscript are significantly different ($P<0.05$)

[2]10 nakfa = 1 US$

SEM = standard error of the mean

Conclusions

The commercial diet was not adequate for starter chicks. Lack of other commercial diets was forcing poultry keepers to make use of the inadequate diet with less than satisfactory results. Reducing the content of wheat middlings and increasing the grain content cannot be a practical solution for a country that so far is not producing all its grain needs for humans even during good rainy seasons. It can be concluded that fishmeal, that can easily be made available by simple sun-drying and grinding, can successfully supplement the commercial diet to make it more complete for starter chicks in Eritrea. Supplementing with fishmeal will guarantee the presence of a minimum level of protein and essential amino acids in the diet. As recommended by FAO (1986) this would be more beneficial for countries where feed mixing and quality control of products are poor and average husbandry conditions are substandard.

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