EFFECT OF FEATHER MEAL AS A SOURCE OF PROTEIN ON THE PRODUCTION OF LAYING HENS

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ABSTRACT

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It has been proposed that more hydrolyzed feather meal can be used in the diet of laying hens than in that of broilers. It was therefore of interest to evaluate the effect of different levels of hydrolyzed feather meal on feed utilization, egg production, feed-efficiency, weight gain and egg quality as measured by Haugh units.

Replicate pens of Single Comb White Leghorn (SCWL) hens were fed rations containing 3, 6 or 9 percent hydrolyzed feather meal with and without supplementation of amino acid (lysine and methionine). The birds were 20 weeks of age when placed on treatment and data were collected for 20 weeks. The birds were confined in individual cages and exposed to 14 hours of light:10 hours of dark throughout the experiment. The experiment was designed so that the orthogonal test for determining linear or quadratic relationship between the hydrolyzed feather meal and interest factors could be utilized.

There was a significant difference ($P < 0.05$) between birds which received the 3 and 9 percent hydrolyzed feather meal with no supplementation of amino acid in egg out-put and egg weight with a

linear decrease from 3 to 9 percent. There was no significant difference in egg production and egg weight ($P > 0.05$) between the control group and those fed 3, 6 or 9 percent hydrolyzed feather meal with supplementation of methionine and lysine. There was no significant difference ($P > 0.05$) between the control and treated groups in feed-intake, feed efficiency, Haugh units or mortality. All the observed factors except mortality changed significantly ($P < 0.05$) by periods in various treatments. Mortality occurred at random in all treatments.

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CHAPTER I

INTRODUCTION

Unavoidable problems of by-product and waste disposal have plagued the poultry slaughtering industry for many years. The problems have become more acute with the development of large scale commercial plants for poultry slaughter. At least 7 kg of feathers are left for every 100 kg of live birds (Mitchell, 1926, 1931). Furthermore, feathers are made up of 80 to 85 percent protein.

Protein supplements in the poultry diets represent one of the major items of cost. Alternate sources of these supplements might have a beneficial effect on production cost providing they are available at a competitive price and are acceptable to poultry.

Feather protein was found to be deficient in tryptophan, methionine, histidine, and lysine (Routh, 1942). It is known that by adding the essential amino acids missing in feather meal one can increase the percentage of this ingredient in the diet without decreasing maximal production (Moran et al., 1969; Bhargava and O'Neil, 1975a; Daghir, 1975). But its usage in feed still is limited because the feather meal is poorly absorbed (Summers et al., 1965), and it also affects the palatability of the feed and decreases feed intake (Van and Payne, 1977).

Both growing and laying birds may be expected to perform below normal as a result of use of feather meal. It is also possible that these protein sources may be put to more extensive use with the hen than with the chicks or broilers. This expectation is based on the knowledge that the protein consumed for maintenance of the hen is higher than for the broiler. The laying hen, because of its larger absolute body size and normally lower rate of net nitrogen accumulation (body tissue plus egg formation) will have a greater amount of its feed devoted to maintenance than will the rapidly growing broiler. This is due to the fact that maintenance in the hen is primarily concerned with synthesis of feather keratin (Leveille and Fisher, 1960) and keratin feed meals have an amino acid pattern nearly perfect to meet this need.

It appears that feather meal might be used to a greater extent with the laying bird.

CHAPTER II

REVIEW OF LITERATURE

Broilers

The broiler industry has expanded tremendously over the past 20 years throughout the world. In 1978, Holly Farms Company broke the billion pounds a year barrier on the live weight basis (Broiler Industry, December 1978).

The top ten countries which lead in broiler production produce more than 9 billion kilograms of meat annually and 700 million kilograms of feathers as indicated in Table 1. Table 2 shows the weekly slaughter of the top eight broiler companies in the United States.

Feather Meal

Mitchell (1926, 1931) reported the feather yield of Leghorns and Rhode Island Reds ranged from 6.6 to 7.6 percent with an average of 7.0 percent of live weight. About 23 percent of the live bird is blood and offal. Feathers are composed of quills, barbs, barbules, and the barbicels, which in the broiler feather processing are cooked and ground together to produce feather meal (Humbert, 1957).

The American Association Feed Control Office (AAFCO) defines hydrolyzed poultry feather as the product resulting from the treatment under pressure of clean undecomposed feathers from slaughtered poultry

Table 1

Chicken Meat, Broilers: Production in Top Ten Countries
(in thousand of metric tons)

	1975	1976	1977	1978
United States	3,666	4,109	4,272	4,604
Japan	616	701	785	825
Brazil	349	552	632	676
Spain	561	617	652	688
France	517	536	561	596
United Kingdom	444	550	555	560
Italy	495	496	500	515
Soviet Union	190	190	387	500
Canada	291	329	340	355
Netherlands	267	292	300	292
Total	7,396	8,372	8,984	9,611

Reports of U.S. Agricultural Attachés, August 1978, Foreign Agriculture Circular, USDA.

Table 2

The Top Eight Broiler Firms in the United States

Firm	Plant Locations	Weekly Slaughter (Head)
Gold Kist	Boaz, Trussville, Ala.; Oak Live, Fla.; Athens, Carrollton, Elligjay, Ga.; Durham, N,C.; Jasper, Texas; Fayetteville, Ark.	5.0 million or more
Holly Farms	Wilkesboro, Monroe, Hiddenite, N.C.; Center, Seguin, Texas; Glen Allen, New Market, Temperanceville, Va.; (*Includes broilers packaged by Holly but processed by others)	4.7 million or more *5.2 marketed
Tyson Foods	Berryville, Green Forest, Nashville, Rogers, Springdale, Ark.; Lola, Kan.; Monett, Mo.; Shelbyville, Tenn.; Springdale, Ark.; Cumming, Ga.; Dobson, Robbins, N.C.	4.0 million or more
Lane Poultry Company	Ashland, Blountsville, Gadsden, Heflin, Ala.; Grannis, Ark.; Broken Bow, Okla.; Fort Worth, Mt. Pleasant (1/2), Wacco, Texas; Dexter, Mo.	3.3 million or more
Perdue Foods	Felton, Georgetown, Del.; Salisbury, Md.; Lewiston, N.C.; Accomac, Va.	2.7 million or more
Valmac Industries	Clarksville, Dardanelle, Pine Bluff, Waldron, Ark.; Logansport, La.; Muskogee, Okla.; Carthage, Nacogdoches, Texas; Swift:Bloomer, Ark. (May 1)	2.6 million or more
Central Soya Company	Athens, Canton, Ga.; Monroe, Robersonville, N.C.; Chattanooga, Tenn.	2.5 million or more
Conagra	Athens, Enterprise, Ala.; Dalton, Ga.; Arcadia, La.	

Broiler Industry, December 1978, p. 17; by permission.

free of additives and/or accelerators. Not less than 75 percent of its crude protein shall consist of digestible protein by the pepsin digestibility method (Proposed, 1961; adopted by AAFCO, 1965).

Agricultural and Industrial Uses

Soil Fertilizer

In the past untreated offal and feathers have been applied to soil as a fertilizer; this method of disposal was generally unsatisfactory (Naber and Morgan, 1956).

Feed

The Keratin proteins have been considered to be of little or no nutritional value because of poor digestibility (Mangold et al., 1930); however, the feather is very high in protein and relatively rich in energy, mineral and fat (Table 3). The development of a method by Binkley and Vasak (1950), for processing feathers into friable, high density meal opened the way for feather meal to successfully supply part of the dietary protein in poultry (Moran et al., 1966, 1967a, 1967b, 1968; Daghir, 1975).

In rations for ruminants, feather meal protein is equal to any protein supplement on a "per unit of protein" basis because amino acid balance doesn't have the same importance as it has in non-ruminant rations. It can be used to replace all of the plant protein supplement when the animals are given a chance to become accustomed to it (Kennett et al., 1972; Morrison, 1971).

Table 3

Composition of Feather Meal

Nutrient Name	Units	NRC Analysis[a]	Scott Analysis[b]
Metabolizable energy	cal/kg	2,360	2,310
Protein	%	86.4	85
Arginine	%	5.42	5.6
Glycine	%	6.31	--
Histidine	%	0.34	--
Isoleucine	%	3.26	--
Leucine	%	6.72	--
Lysine	%	1.67	1.5
Methionine	%	0.42	0.5
Cystine	%	4.00	3.0
Phenylalanine	%	3.26	--
Threonine	%	3.43	--
Tryptophan	%	0.50	0.5
Valine	%	5.57	--
Total fat	%	3.30	2.5
Total fiber	%	1.00	1.5
Calcium	%	0.33	0.2
Available phosphorous	%	0.55	0.6
Sodium	%	0.71	--
Thiamine	mg/kg	0.10	--
Niacin	mg/kg	27.00	24.0
Riboflavin	mg/kg	2.10	2.0
Pantothenic acid	mg/kg	10.0	11.0
Vitamin B-12	mg/kg	0.078	--
Choline	mg/kg	891.00	900.0
Pyridoxine	mg/kg	--	--
Folacin	mg/kg	0.20	--
Biotin	mg/kg	0.44	--
Potassium	%	0.44	--
Magnesium	%	0.20	--

[a]National Research Council, 1977.

[b]Scott, Nesheim and Young, 1976.

Factors Affecting Utilization of Low Quality Feather Protein by Poultry

The two most important factors which influence utilization of low quality feather protein by animals are feed intake and digestibility.

Feed Intake

When protein feed supplements are in short supply feather meal might be a suitable ingredient in feed for laying hens and broilers (Sullivan and Stephenson, 1957; Bhargava et al., 1975b). However, the feed intake will decrease as the level of feather meal is increased in the diet (Bhargava and O'Neil, 1975b; Moran et al., 1969).

Van and Payne (1977) pointed out that the higher amino acid supplementation of feeds with protein sources deficient in some amino acids is much more critical on low feed intake.

Digestibility

Approximately 85 to 90 percent of the protein from feather meal comes from keratin (Harrap and Woods, 1964). The keratins are classified in the sclero-protein group because of their insolubility in aqueous solvents (Fruton and Simmonds, 1960). This keratin must be hydrolyzed in order that it may be digested by animals. According to the AAFCO official definition for hydrolyzed feather meal, 75 percent of its crude protein shall consist of protein that is digestible by pepsin.

Chemical Structure of Feather Protein

The chemical structure of keratin consists of chains of amino acids joined by peptide bonds formed by a combination of the amino group of one acid to the carboxyl group of the next. A large number of amino acid residues are linked into a single molecule. Assuming all the protein of feather is keratin, the molecular weight is 10,400 (Harrap and Woods, 1964). In their native state, these molecular chains are arranged in an orderly manner, stabilized primarily by hydrogen bonds which can be broken by chemicals or heat. When these bonds are broken, the protein loses its original native properties and is denatured.

The great stability of keratin is due to a cystine disulfide cross link, a central bond between the two sulfur atoms (covalent bonds); 8.8 percent of this protein is cystine (Block and Bolling, 1951).

The structure of feather keratin may be visualized as extended chains of amino acids bonded together by hydrogen bonds and cross linked by disulfide bonds.

Chemical Studies on Keratin (Wool and Feather)

The insolubility of keratins and their resistance to digestion by enzymes have to be explained on the basis of protein structure. Many investigators have studied these properties and have attempted to alter them. Kuhne in 1877 observed that the keratin of hair was made digestible by pepsin when surface area was increased by mechanical means. Powdered wool was used by Harris and his coworkers (1932) in studies on isoelectric point, the amino nitrogen content (Kanagy and Harris, 1935).

Routh et al. (1938) observed that after wool was ground the powdered material was digested by both pepsin and trypsin. An appreciable fraction of the nitrogen and sulfur of powdered keratin was soluble in water.

Scott and Payne (1926-1928) showed that hydrolyzed feathers improved egg production in one year, but not in the second year, and these researchers concluded that feathers added nothing of importance to poultry diets and the cost of hydrolyzing was too great to allow the use of feather keratin in practical poultry feeds. Balance studies conducted by Mangold and Dubiski (1930) failed to show any digestion of white goose feathers by cats, owls, dogs, and rats. Thus, it appeared that native feather keratin was not only seriously deficient in certain amino acids but also poorly digestible.

It was found that powdered feathers were capable of supporting moderate growth in the young rats when supplemented with methionine, lysine, tryptophan and histidine (Routh, 1942).

Processing Effects on Low Quality Feather Protein

The discovery of a processing method for poultry by-products opened a way for researchers to use more of these products as feed. Figure 1 shows the normal processing.

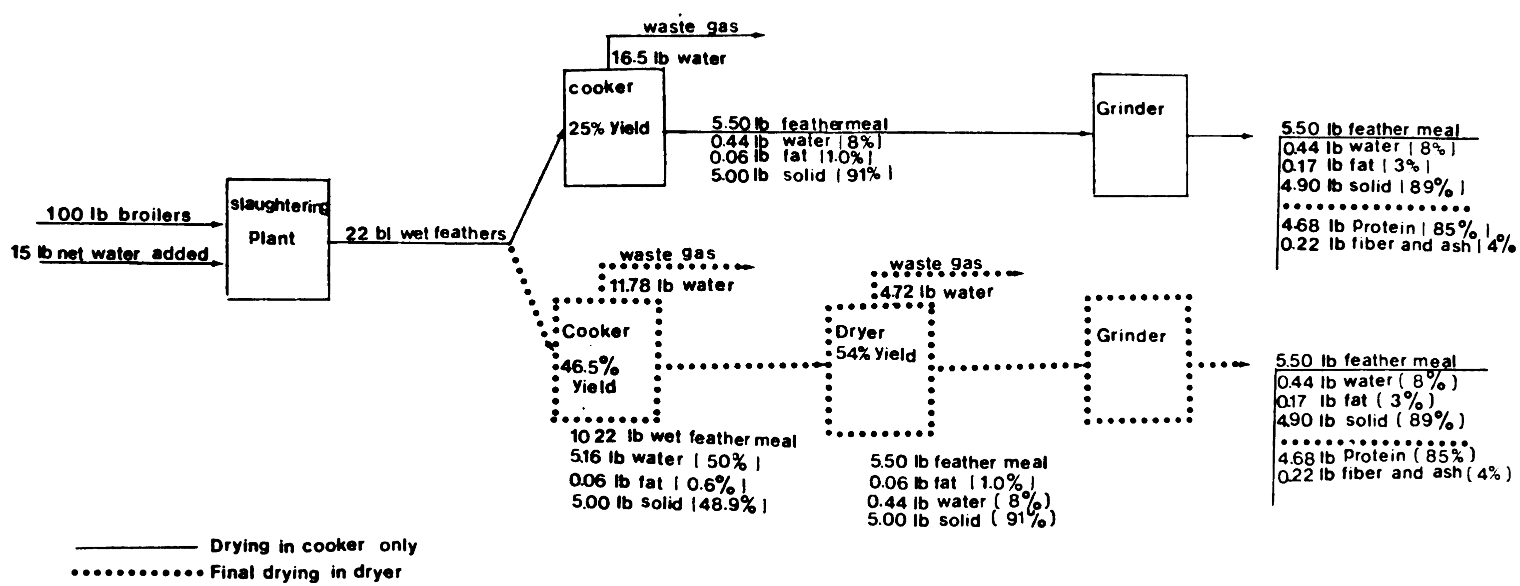

Figure 1. Broiler Feather Processing.

Marketing Research Report, June 1957, USDA, Washington, D.C.

<u>Cooking</u>

The quality of by-products can be influenced during cooking by either physical or chemical means. Elevated temperature and prolonged cooking time promote chemical changes, especially oxidation of the fat. It is recommended that the temperature during cooking definitely not be allowed to go over 250° F. Also, for maintaining fat quality, cooking should not be continued for more than two hours. The fact that poultry offal usually takes longer to cook than wastes from other animals makes it more difficult to obtain a high-quality fat from poultry offal. It has been claimed that partially cooking poultry offal in a cooker and completing the drying in a separate dryer will give better fat quality. It also appears that higher temperatures (>250° F) cause the by-product meal to have a low digestibility and a low nutritive value (Othmor, 1954).

Studies on flame drying and steam-tube drying of fish meal, where presumably the flame drying caused higher temperature in the meal, did not show any difference in digestibility of the fish meal (Grau et al., 1955; Almquist, 1956). Overcooking to the point of burning the tankage and forming a rubbery carbonized product with low feed value is possible if cooking temperatures are not controlled. Overcooking will also reduce the yield of fat during subsequent pressing.

Physical changes in quality result from agitation and overcooking. Some renderers feel that less fines are produced (which subsequently press out with fat) if the agitator speed is kept below

20 rpm instead of the commonly used 38 rpm (Humbert, 1957). The lower agitator speed will increase the required cooking time. Overcooking and making the tankage too dry causes more fines than higher agitating speed does.

"In summary, one can qualitatively state that low cooking temperatures, low agitation speed, and short cooking time will tend to give a better quality product" (Humbert, 1957).

Final moisture content is important in that it indicates whether the cooker batch is overcooked or undercooked. Eight percent moisture in the tankage is usually assumed to be the optimum moisture content. The effect of undercooking results in too much moisture and poor pressing characteristics of the tankage.

Drying

Separate dryers are used to increase production by reducing the time the tankage must be held in the cookers. Generally, the tankage must be removed from the cookers in half the time normally required if separate drying is used. The use of separate dryers is quite common for feather meal. Use of separate dryer probably reduces the agitation and grinding effect on the tankage (Humbert, 1957).

It is possible to overheat the tankage in a dryer. However, the drying temperature had to be lowered to reduce the obnoxious odors given off. (When the material-exit temperature was reduced from 160-170° F down to 140-150° F, the amount of the odor was reduced and the color of the feather meal became lighter, indicating better quality [Harstad, 1956].)

Fat Extraction

Storage of offal before pressing to extract fat will reduce the quality of the by-product meal and fat. The fat present in the offal tends to be oxidized and become rancid. If a suitable stabilizer (antioxidant) has been added during the cooking, the problem of rancidity developing during storage of the tankage before pressing is reduced. A high moisture content of the tankage promotes hydrolysis and thus increases the chances of spoilage.

The pressing itself does not alter the quality of fat significantly, unless the equipment is not kept clean. The moisture in the fat is primarily influenced by the cooking operation. If the pressing is not properly operated, the by-product meal can have too high a fat content, which may promote spoilage of the meal. This high fat content will also make the subsequent grinding operation more difficult.

Grinder

Grinding must be performed at some stage before poultry by-products are compounded into animal feeds. In some cases small renderers may not grind any of their by-products but sell them as pressed cakes or unground feather meal and unground dried blood.

Hammermills are used to obtain the finished grind, commonly to 8 or 12 mesh. In some instances, separate crushers are used to break the pressed cake and obtain a material that can be fed to the hammermill. However, many hammermills are manufactured with a built-in cake crushing mechanism. The power required to grind a specific quantity of material will depend on the particle size to which it is ground. A relatively coarse material may be produced with only 10 horsepower per ton per hour of capacity, while a relatively fine material may require 25 horsepower per ton per hour of capacity (Humbert, 1957).

Feather Meal in Poultry Rations

On the basis of the amino acid content of keratins given by Graham et al. (1949) and from the amino acid contents of the other dietary ingredients (Almquist, 1952), it is apparent that keratin from feathers can substitute for a large portion of soybean oil meal in commercial chick rations without distrurbing the amino acid balance of the ration (Wilder et al., 1953; Sullivan and Stephenson, 1957; Naber et al., 1961; Poppe, 1965; Vogt and Stute, 1975).

Since feather meal has a good replacement value for the chicks at high protein dietary levels (20 to 23 percent) and poor substituting ability at low dietary levels (15 percent), Sibbald et al. (1962) suggested that feather meal was being used as a source of non-specific nitrogen. Studies conducted by Naber et al. (1956) showed that feather meal and poultry meat scrap were capable of replacing 5 percent or one-fourth of the protein in broiler rations containing large amounts of soybean oil meal and corn fortified with fish meal, dried whey product, methionine, minerals, vitamins and antibiotics. McKerns and Rittersporn (1958) substituted keratin for 50 percent of the soybean oil meal equivalent to 25 percent of the total diet, keratin meal improved the feed efficiency. Wilder et al. (1953, 1955) also found a growth response from feather meal when fed to chicks. Gerry et al. (1954) and Morris and Balloun (1971, 1973) reported that feather meal substituted for one-fourth of the total protein in the diet had no adverse effect on growth of broilers.

In the studies by Burgos et al. (1974) and Bhargava et al. (1975a), poultry offal meal and hydrolyzed feather meal were blended to evaluate poultry by-product and hydrolyzed feather meal (PBHFM) as a protein supplement in the diet of broiler chicks. There were no adverse effects on body weight and feed efficiency when PBHFM was incorporated into the diet to the level of 10 percent. But the addition of either 15 or 20 percent (one-fourth of the total protein) PBHFM significantly depressed growth and feed efficiency.

Very few studies have been reported on the use of feather meal in rations of laying hens. Moran et al. (1969) studied the effect of feather meal and hog hair meals (keratin) as sources of protein for laying hens with 10 percent protein based on 5 percent from soybean and 5 percent from corn. When the diet was supplemented with methionine the diet was shown capable of supplying the estimated minimal essential amino acid needs of laying hens (Leveille and Fisher, 1960). However, the diet was unable to support maximal performance. Also, by adding 5 percent keratin meals to the basal diet, it was found that several measured parameters of performance were improved comparable to the basal diet, but that supplemental methionine was necessary for maximal production and egg weight. Van and Payne (1977) conducted two experiments. In the first one, the control diet was compared with five diets that contained 7 percent hydrolyzed feather meal (HFM) which varied in lysine content. The basal diet was very deficient in lysine. As lysine supplementation was increased, egg production, feed consumption and live-weight increased, and improved feed efficiency occurred. In the second experiment, the control diet was compared with five diets that contained 7 percent HFM which varied in methionine, lysine and tryptophan. When the diet with HFM was supplemented with all three of the above amino acids to a level higher than that in the control diet, a satisfactory level of performance was obtained. Their study in the methionine supplementation for increasing egg output was in agreement with the work of Moran et al. (1969). The effect of tryptophan supplementation was explained partly by the deleterious effect of HFM in poultry diets as indicated by Daghir (1975) and Macalpine and Payne (1977). Moran also concluded that the lower egg production confirms the suspicion that not all lysine measured by amino acid analysis in HFM is available to poultry.

CHAPTER III

OBJECTIVES

Interest in the use of feather meal for poultry feed is increasing as the prices of quality protein feeds increases. At present, millions of pounds of feather meal available annually are utilized as feed. The potential use of feather meal is worthy of consideration in view of the low price of its protein unit content. Feather meals are essentially protein feeds, low in fiber and relatively high in calcium, phosphorous and fat. Tsang et al. (1963) incorporated hydrolyzed feathers in a series of broiler rations. Based on actual chemical analysis, it was calculated that approximately 40 kilograms of hydrolyzed poultry feather and 35 kilograms of ground yellow corn would supply the same amount of protein and productive energy as 70 kilograms of dehulled soy-bean meal and 5 kilograms of stabilized animal grease.

Feather meals cannot be the sole source of protein in poultry rations, because of the imbalance of amino acids and because the protein of feather meal is poorly absorbed (Summers et al., 1965).

The objectives of this study were to determine:

1. the effect of utilization of feather meal on production of laying hens.
2. to what level commercial feather meal can be used without decreasing egg production and/or egg quality.

CHAPTER IV

EXPERIMENTAL PROCEDURE

The experiment was conducted at the Michigan State University Poultry Science Research and Teaching Center, from December 15, 1978 to May 3, 1979.

Experimental Design

Twenty-week-old Single Comb White Leghorn (SCWL) pullets were sorted into groups of similar weight. Pullets were selected (omitting the extremes of heavy- and light-weight ones), weighed and distributed into groups according to average weight. They were housed in individual laying cages (19 centimeters wide X 36 centimeters high X 33 centimeters deep) with double deck. A chart of random numbers was used so that each part of a deck would have each particular replicate. This was done to reduce the chance of having a treatment group on a particular deck be more favorably treated than those placed elsewhere.

Treatments

The experiment consisted of seven treatments with three replicates each. There were eight birds within each replicate with a single feeder. The treatments were designed to consist of seven rations as follows:

1. Control ration (A) with no feather meal[1] in it.
2. Ration (B) with 3 percent feather meal supplemented with amino acids.
3. Ration (C) with 6 percent feather meal supplemented with amino acids.
4. Ration (D) with 9 percent feather meal supplemented with amino acids.
5. Ration (E) with 3 percent feather meal without supplementation of amino acids.
6. Ration (F) with 6 percent feather meal without supplementation of amino acids.
7. Ration (G) with 9 percent feather meal without supplementation of amino acids.

The control diet used for this experiment is shown in Table 4. It is basically a corn-soybean type diet satisfying all the nutrient requirements of the laying chicken. In all rations total energy and protein content of the diet were adjusted by changing the amount of corn and soybean. Ration G was further adjusted by changing the amount of the fish meal in the diet. Therefore all rations provided isocaloric and isonitrogenous contents (Table 5). The composition and calculated analysis of nutrients of the experimental rations are shown in Table 6.

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[1]Feather meal contained minimum 85 percent protein, minimum 2 percent fat and minimum 6 percent moisture manufactured by Badger By-Products Company, 511 E. Menomonee Street, Milwaukee, Wisconsin 53202.

Table 4

Composition of Control Diet Used for the Experiment

Ingredients	Percentage of Ration[a]
Corn	59.57
Soybean 49%	18.50
Fish meal MH	3.00
Wheat middling	5.00
Fat hydrolyzed	1.80
Alfalfa 17%	3.00
Limestone	6.70
Methionine DL	0.006
Dical	1.50
Salt	0.427
Premix[b]	0.50

[a]As fed basis.

[b]Supplies the following per kilogram of ration: 8800 USP vitamin A; 2750 ICU vitamin D_3; 7.7 mg riboflavin; 13.64 mg pantothenic acid; 27 mg of niacin; 429 mg choline chloride; 1.1 mg folic acid; 0.0013 mg vitamin B-12; 5.5 IU vitamin E; 1.65 mg menadione sodium bisulfite; 64 mg manganese; 1 mg iodine; 4 mg copper; 251 mg cobalt; 50 mg zinc; 25 mg iron; 500 mg magnesium.

Table 5

Composition of Rations (%) With Different Levels of Hydrolyzed Feather Meal (HFM)

Feed Description	Control Ration (A)	Ration (B) 3% HFM+	Ration (C) 6% HFM+	Ration (D) 9% HFM+	Ration (E) 3% HFM-	Ration (F) 6% HFM-	Ration (G) 9% HFM-
Corn	59.56	63.00	66.45	67.96	63.44	67.25	70.40
Soybean 49%	18.50	12.60	6.70	2.20	11.63	4.82	0.67
Fish meal MH	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Wheat mid.	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Fat hydrolyze	1.80	1.20	0.70	0.60	1.80	1.80	1.80
Alfalfa 17%	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Limestone	6.70	6.70	6.70	6.70	6.70	6.70	6.70
Methionine DL	0	0.031	0.057	0.075	0.006	0.006	0.006
Dical	1.50	1.50	1.40	1.30	1.50	1.50	1.50
Salt	0.427	0.378	0.329	0.28	0.427	0.427	0.427
Feather meal	--	3.00	6.00	9.00	3.00	6.00	9.00
Lysine	--	--	0.067	0.28	--	--	--
Premix	0.50	0.50	0.50	0.50	0.50	0.50	0.50

HFM+ = Hydrolyzed feather meal with supplementation of amino acids.
HFM- = Hydrolyzed feather meal without supplementation of amino acids.

Table 6

Calculated Ration Nutrient Composition (% of Ration)

Nutrient	Control Ration (A)	Ration (B) 3% HFM+	Ration (C) 6% HFM+	Ration (D) 9% HFM+	Ration (E) 3% HFM-	Ration (F) 6% HFM-	Ration (G) 9% HFM-	NRC Value[a]	Scott Value[b]
Crude protein	17.55	17.55	17.55	18.13	17.05	16.60	16.20	0.60	0.72
Lysine	0.94	0.80	0.69	0.69	0.77	0.60	0.413	0.60	0.72
Meth - DL	0.31	0.31	0.31	0.31	0.275	0.25	0.202	0.27	0.34
Meth + cys	0.58	0.60	0.62	0.65	0.559	0.549	0.513	--	--
Tryptophan	0.23	0.20	0.18	0.16	0.197	0.163	0.133	0.11	0.17
Calcium	3.12	3.12	3.12	3.12	3.15	3.14	3.12	--	--
Avail. phosphorus	0.48	0.48	0.48	0.48	0.48	0.49	0.45	--	--
Sodium	0.21	0.21	0.21	0.21	0.23	0.248	0.26	--	--

[a]These figures were extracted from the National Research Council, 1977; Nutrient requirements of poultry.

[b]Figures from Scott, Nesheim and Young, 1976; Nutrition of the chicken.

Management and Feeding Program

The house was ventilated (0.25 to 4.0 CFM/bird) and incandescent light was supplied 14 hours a day at 0.5 ft. candles intensity. All rations were prepared at the poultry farm. Feed and water were supplied ad libitum. The amount of feed offered to each group of hens and the amount refused was weighed and recorded every 28 days (one period) in order to determine feed-intake. Daily records of egg production were kept except for the first five days in order that the animals could get accustomed to the new diets. During the last three consecutive days of each period eggs were weighed and broken on a glass plate for direct measuring of the Haugh units. The birds were weighed individually at the beginning and at the termination of the experiment. Records of mortality were maintained.

Statistical Analysis

All data were analyzed by analysis of variance, orthogonal polynomials, using General Linear Model (GLM), Quadratic Model subroutine of Statistical Analysis System (SAS). Significant differences between means of treatment, overall means of supplemented and unsupplemented hydrolyzed feather meal rations were tested at the level of 5 percent (Appendix, Tables 14 through 20) by the use of Split-Plot repeat measurement procedure (Snedecor and Cochran, 1967).

CHAPTER V

RESULTS AND DISCUSSION

The effects of various treatments and/or lysine and methionine supplements on performance are shown in Table 7.

Production

The percent production did not show a significant difference between the means of treated and control groups (Appendix, Table 14). Work by Leveille and Fisher (1960) showed diets at the level of 7 percent HFM (Hydrolyzed Feather Meal) with supplemental methionine were capable of supplying the estimated minimal essential amino acids, but it was unable to support maximal production. In the present experiment the percentage of lysine and methionine became lower than the NRC requirement for the laying hens only at the level of 9 percent HFM with no supplementation of amino acids (Table 6). There was a significant ($P < 0.05$) difference between the percentage of egg production of the birds receiving the 3 percent hydrolyzed feather meal diet with no supplementation of methionine and lysine (HFM-) and those receiving the 9 percent HFM- diet (Appendix, Table 14). Figure 2 shows that the percentage of production was generally higher in the hens that were fed the diet with 3 percent HFM+ than in the control group.

Table 7

The Effect of Dietary Supplementation With Methionine, Lysine and Mixture of Essential Amino Acids to HFM (Hydrolyzed Feather Meal) Diets on Performance of Laying Hens

Treatments	% Production	Egg Weight[b]	Feed Consumption (grams) /Egg	Feed Consumption (grams) /Hen/Day	Haugh[b] Unit	Weight Gain (grams)/ Bird/140 Days
Control	62.75	55.78	193.3	121.1	88.0	224.8
3% HFM+[c]	69.39	56.19	191.7	131.4	87.6	264.6
6% HFM+	58.68	55.58	242.0	133.2	89.1	378.9
9% HFM+	59.43	56.76	230.3	128.2	89.1	314.3
3% HFM-[d]	73.18	56.45	179.9	131.4	86.7	275.0
6% HFM-	69.75	54.31	177.0	122.8	89.5	338.1
9% HFM-	52.93	53.46	226.9	120.0	91.0	126.4

[a]Percent of production for whole periods (20 to 40 weeks of age).

[b]Each datum is the average of 120 eggs.

[c]HFM+ = Hydrolyzed feather meal with supplementation of amino acids (lysine and methionine).

[d]HFM- = Hydrolyzed feather meal with no supplementation of amino acids.

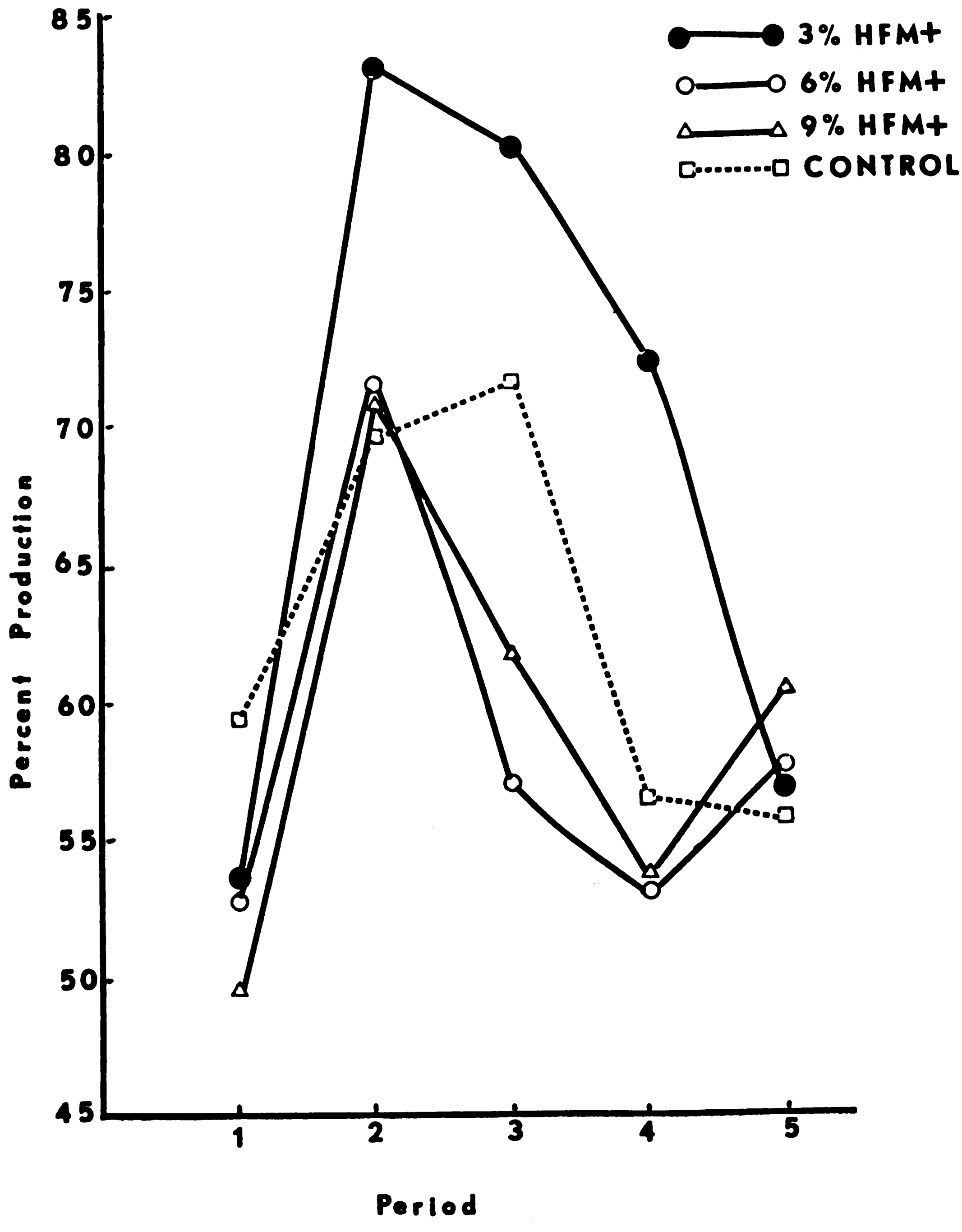

Figure 2. Percent Production Response by Period for Control and Supplemented Groups.

There was no significant difference in percent production of hens fed the diets supplemented with HFM+ (Appendix, Table 14). Egg production of the hens which were fed the diets with 3 and 6 percent HFM, whether supplemented or unsupplemented, improved when the amino acid requirement was not lower than that of National Research Council (Figures 2 and 3). Production was higher at 3 than at 6 percent HFM. Peak production occurred in all treated groups at an earlier age than in the control birds (Table 8 and Figures 2 and 3). Thus, there may be some factor or factors in the hydrolyzed feather meal (HFM) which stimulated the birds to peak earlier.

Figure 4 shows that increasing the percentage of HFM in the diet of laying hens linearly decreased the percentage of production. This reduction of production by additional HFM was statistically significant ($P < 0.05$) for the hens that were fed rations with no supplementation of lysine and methionine (Appendix, Table 14).

The percentage of production significantly ($P < 0.05$) changed by periods. Peak production was achieved between 24 and 28 weeks of age for all test groups and between 28 and 32 weeks of age for the control group (Figures 2 and 3).

Egg Weight

There was no significant difference between weights of eggs produced by treated hens and those produced by control hens (Appendix, Table 15). Van and Payne (1977), in comparing a control diet with one containing 7 percent HFM, showed that as supplementation of lysine

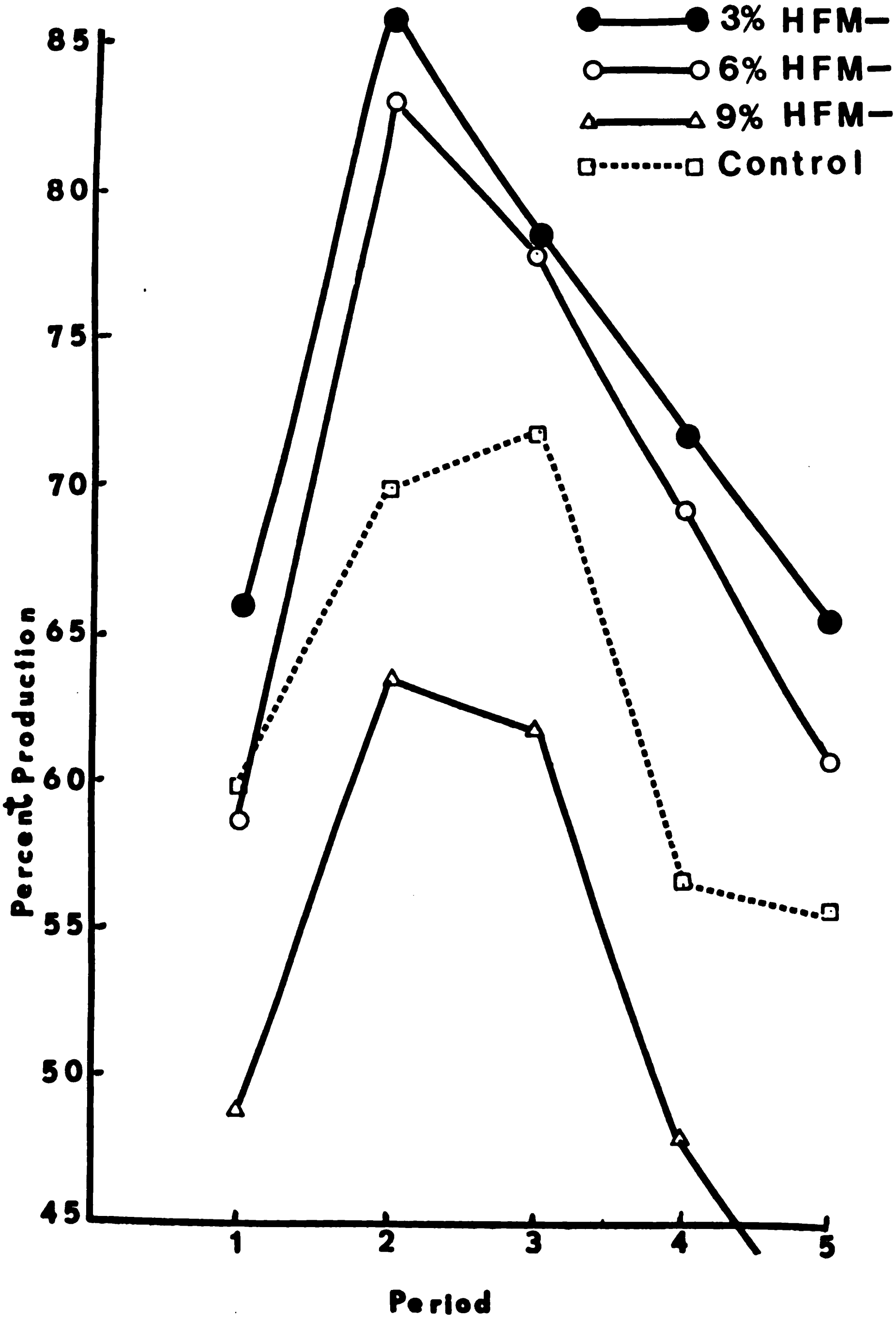

Figure 3. Percent of Production Response by Period for Control and Unsupplemented Groups.

Table 8

The Percentage of Production in the Control Group, Supplemented and Unsupplemented Groups

Treatments	Periods[a]				
	1st	2nd	3rd	4th	5th
Control[b]	59.8	69.9	71.57	56.5	55.9
Average of supplemented[c]	52.1	75.1	66.4	59.9	58.46
Average of unsupplemented[c]	57.7	77.7	72.5	62.5	56.0

[a]Each period is 28 days long.

[b]The percentage of production in this row is obtained from 24 birds.

[c]The percentage of production in these rows are obtained from 72 birds.

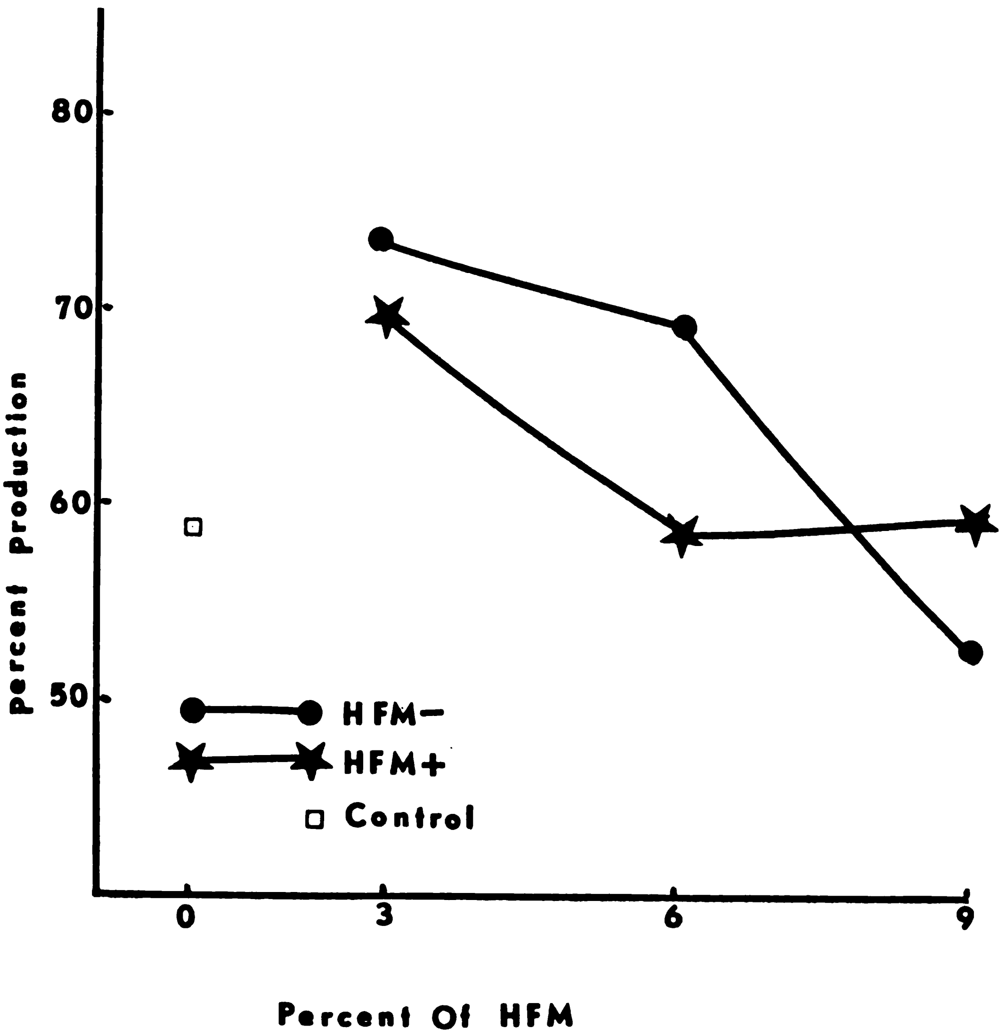

Figure 4. Percent of Production Response to HFM.

increased egg weight improved. This was supported by the present experiment (Figure 5), but it was not true when no supplementation was added. Figure 5 shows that the egg weights were suppressed when no supplementation of lysine and methionine were put into the diets. Moran et al. (1969) showed the increase in egg weight resulting from the addition of amino acids into the diets containing 5 percent HFM.

Egg weight from all groups of birds increased throughout the duration of the experiment. However the egg weight increased significantly more ($P < 0.05$) in the hens which were fed diets with lysine and methionine supplementation than in those with no supplementation of amino acids (Appendix, Table 15 and Figure 6). Table 9 shows the average egg weight for each period. The average egg weight was significantly ($P < 0.05$) less in the hens which were fed with 9 percent HFM- than in those fed the 3 percent HFM- diet (Appendix, Table 15). Also the average egg weight from the hens which were fed the diets with HFM- (with no supplementation of amino acids) was significantly lower ($P < 0.05$) than that of eggs from the supplemented groups (Appendix, Table 15).

Feed Consumption and Nutrient Intake

Feed consumption by periods is shown in Table 10. There were no significant differences in feed consumption due to treatments (Appendix, Table 16). Figure 7 shows the relationship between feed consumption and percentage of HFM.

Moran et al. (1969) demonstrated an improvement in feed-intake by adding 5 percent HFM while maintaining the lysine and methionine

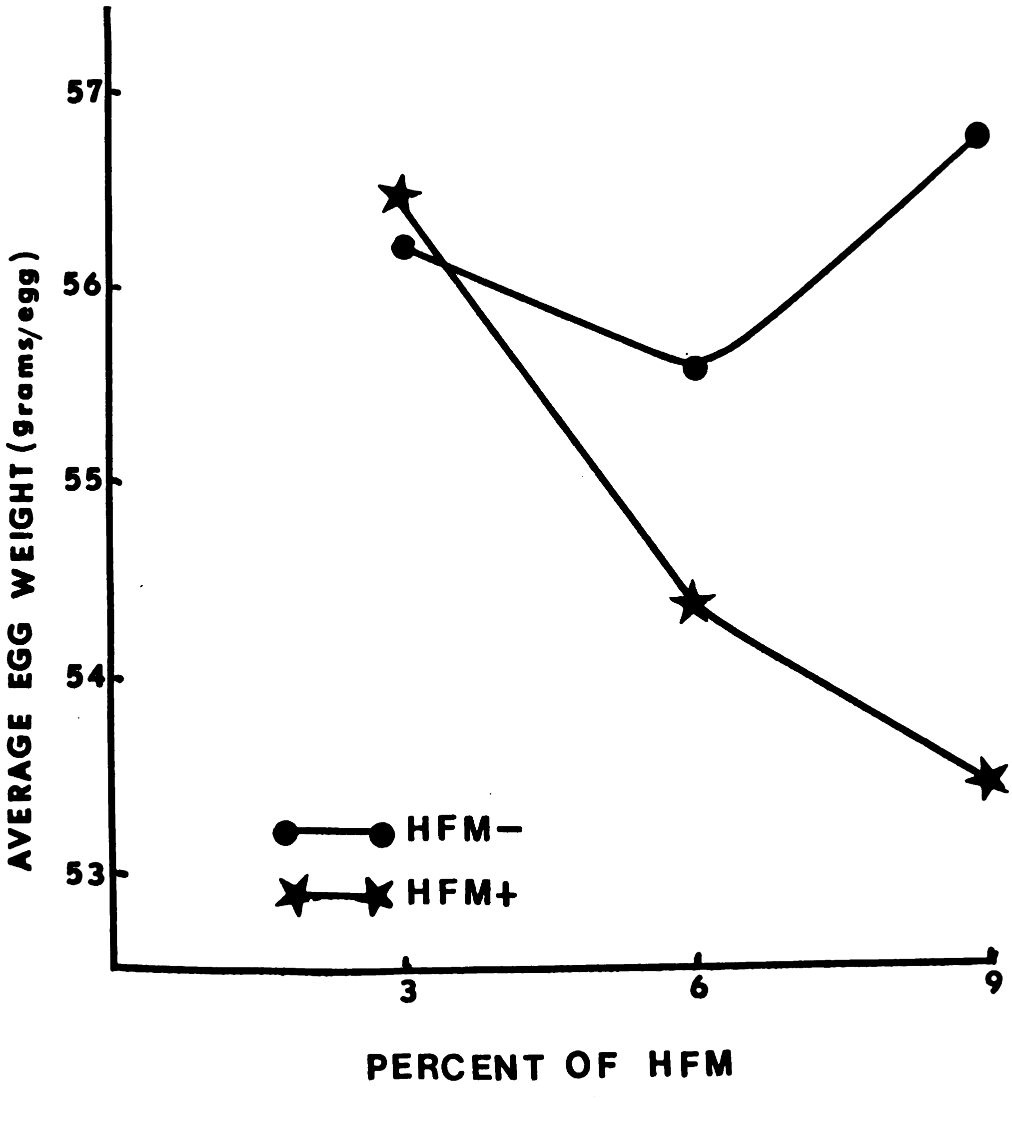

Figure 5. Egg Weight Response to HFM in Diets.

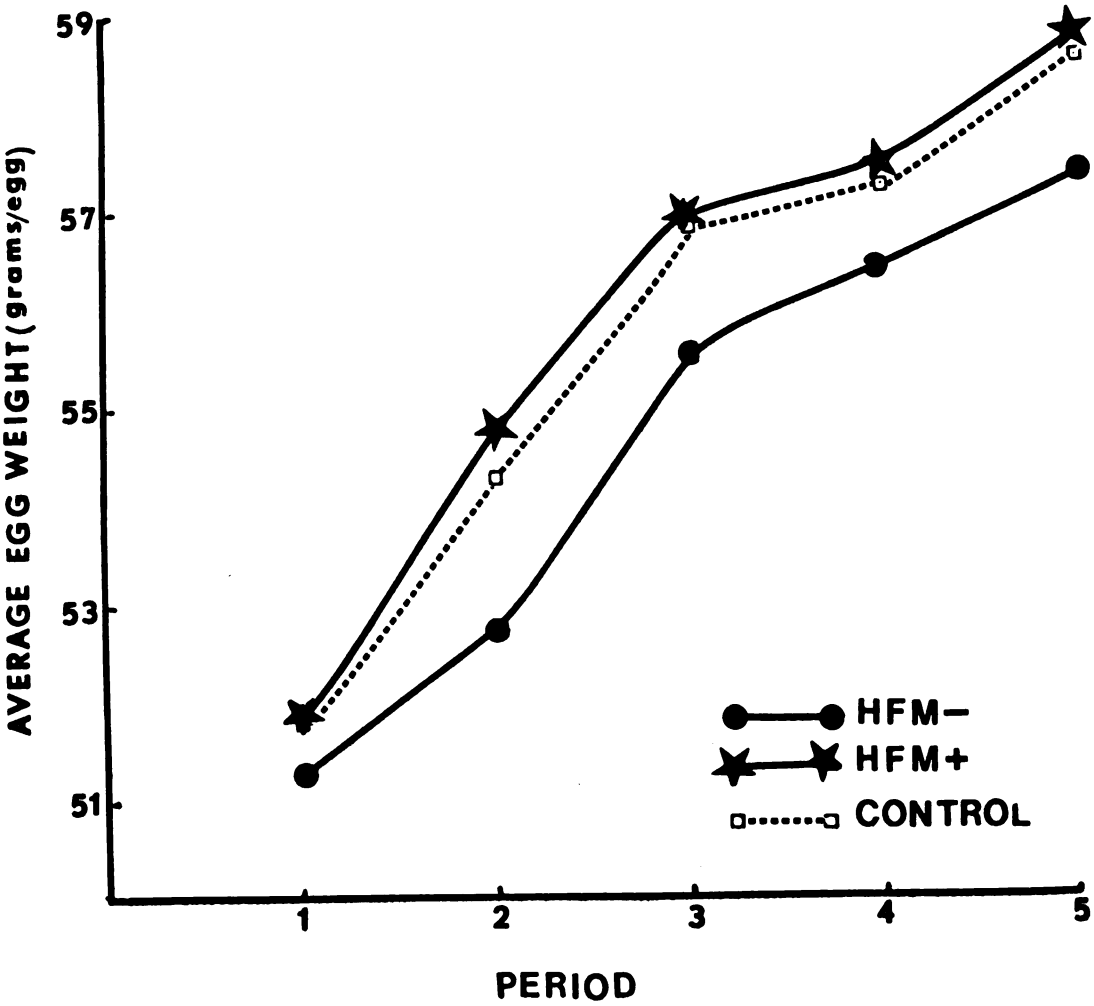

Figure 6. Egg Weight Response to Periods.

Table 9

The Average of Egg Weight in the Control Group, Supplemented and Unsupplemented Groups

Treatments	Periods[a]				
	1st	2nd	3rd	4th	5th
Control[b]	51.8	54.3	56.9	57.3	58.6
Average of supplemented[c]	51.8	54.8	57.0	58.4	58.8
Average of unsupplemented[c]	51.3	52.8	55.6	56.5	57.4

[a]Each period is 28 days.

[b]The average of egg weight in this row obtained from 72 eggs (grams/egg).

[c]Each datum in these rows is the average of 216 eggs (grams/egg).

Table 10

The Average of Feed Consumption in the Control Group, Supplemented and Unsupplemented Groups (grams/hen/day)

	Periods[a]				
Treatments	1st	2nd	3rd	4th	5th
Control[b]	113.7	125.0	126.8	114.4	126.2
Average of supplemented[c]	111.6	129.9	128.9	134.0	139.0
Average of unsupplemented[c]	102.5	129.4	132.0	128.6	125.6

[a]Each period is 28 days.

[b]Each datum is the average of 24 birds consumption (grams/hen/day).

[c]Each datum in these rows is the average of 72 birds consumption (grams/hen/day).

requirement for laying hens in the diets. In this study there was not any significant ($P > 0.05$) change of feed-intake in the treated groups whether it is supplemented or not (Appendix, Table 16). The level of protein and age of birds used may explain this difference. The feed-intake significantly ($P < 0.05$) changed by periods (Appendix, Table 16). Figure 8 shows the relationship between feed consumption and periods in the treated and control groups. Table 11 shows that there was little difference between calories and proteins intake among the treatments. Lysine and methionine intake varied from 1.138 and 0.375 to 0.495 and 0.242 grams/hen/day, respectively.

Feed Conversion

Feed efficiency for birds on each treatment is shown in Figure 9. There was no significant ($P > 0.05$) difference in feed conversion between the birds receiving the supplemented rations (HFM+) and those receiving the unsupplemented rations (HFM-).

The results obtained with 3 and 6 percent HFM with and without supplementation of amino acids did not improve the feed efficiency (Appendix, Table 17 and Figure 9). However, the level of lysine and methionine matched the NRC requirement for the laying hens. Moran et al. (1969) showed the improvement of feed efficiency in the hens that were fed at 5 percent HFM with supplementation of amino acids. Van and Payne (1977) carried out an experiment which showed the improvement of feed efficiency at the level of 7 percent HFM into the ration of laying hens when the amino acids were supplied to the requirement level of laying hens. These variations of results

Table 11

Nutrient Consumption

Nutrient	Ration (A) Control	Ration (B) 3% HFM+	Ration (C) 6% HFM+	Ration (D) 9% HFM+	Ration (E) 3% HFM-	Ration (F) 6% HFM-	Ration (G) 9% HFM-
Calorie[a]	346.8	376.2	381.4	367.1	367.2	351.6	343.6
Crude protein[b]	21.25	23.06	23.37	23.24	22.40	20.38	19.44
Lysine[b]	1.138	1.051	0.919	0.884	1.011	0.737	0.495
Methionine-DL[b]	0.375	0.407	0.413	0.397	0.361	0.307	0.242
Tryptophan[b]	0.278	0.263	0.239	0.205	0.259	0.200	0.159
Calcium[b]	3.78	4.10	4.15	4.00	4.14	3.85	3.74

[a]Calorie/hen/day.

[b]Grams/hen/day.

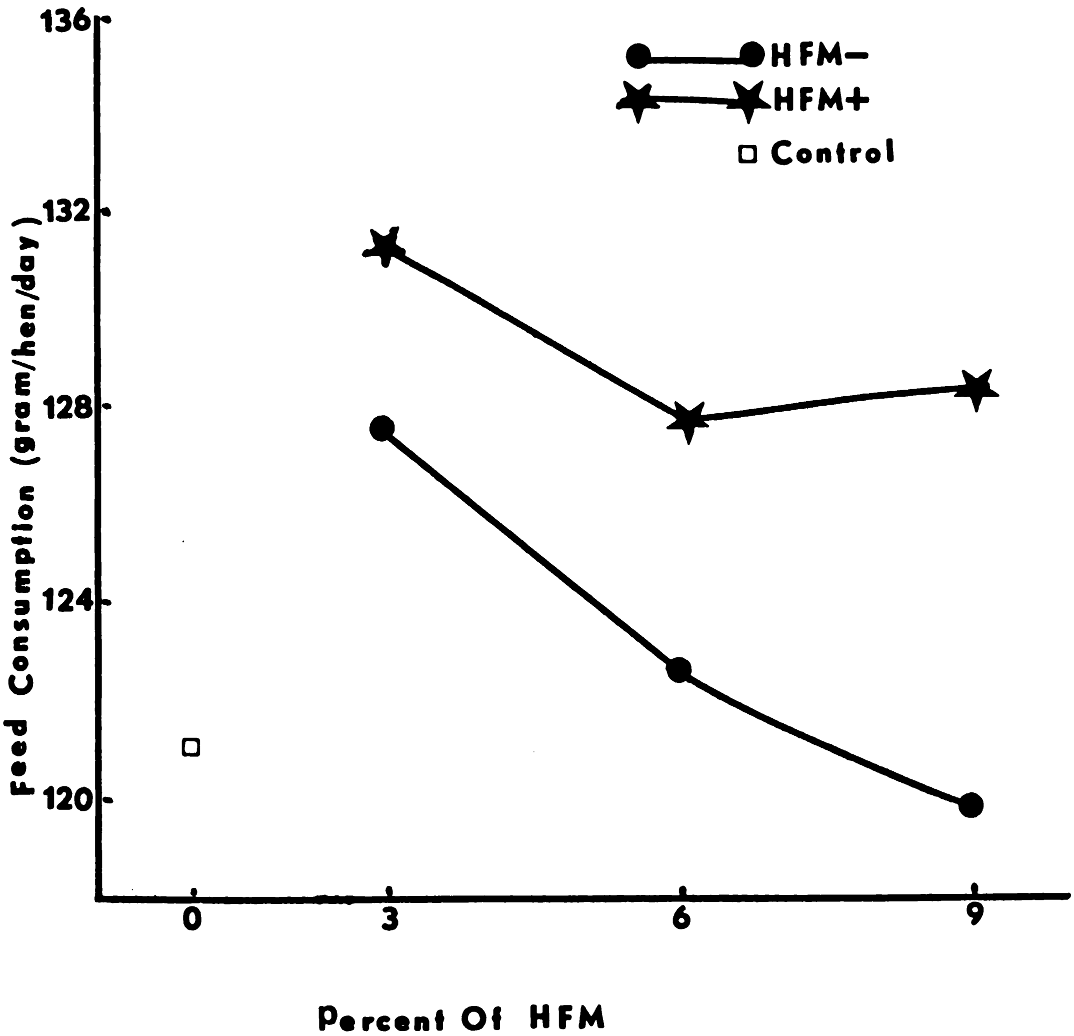

Figure 7. Feed Consumption Response to HFM in Diets.

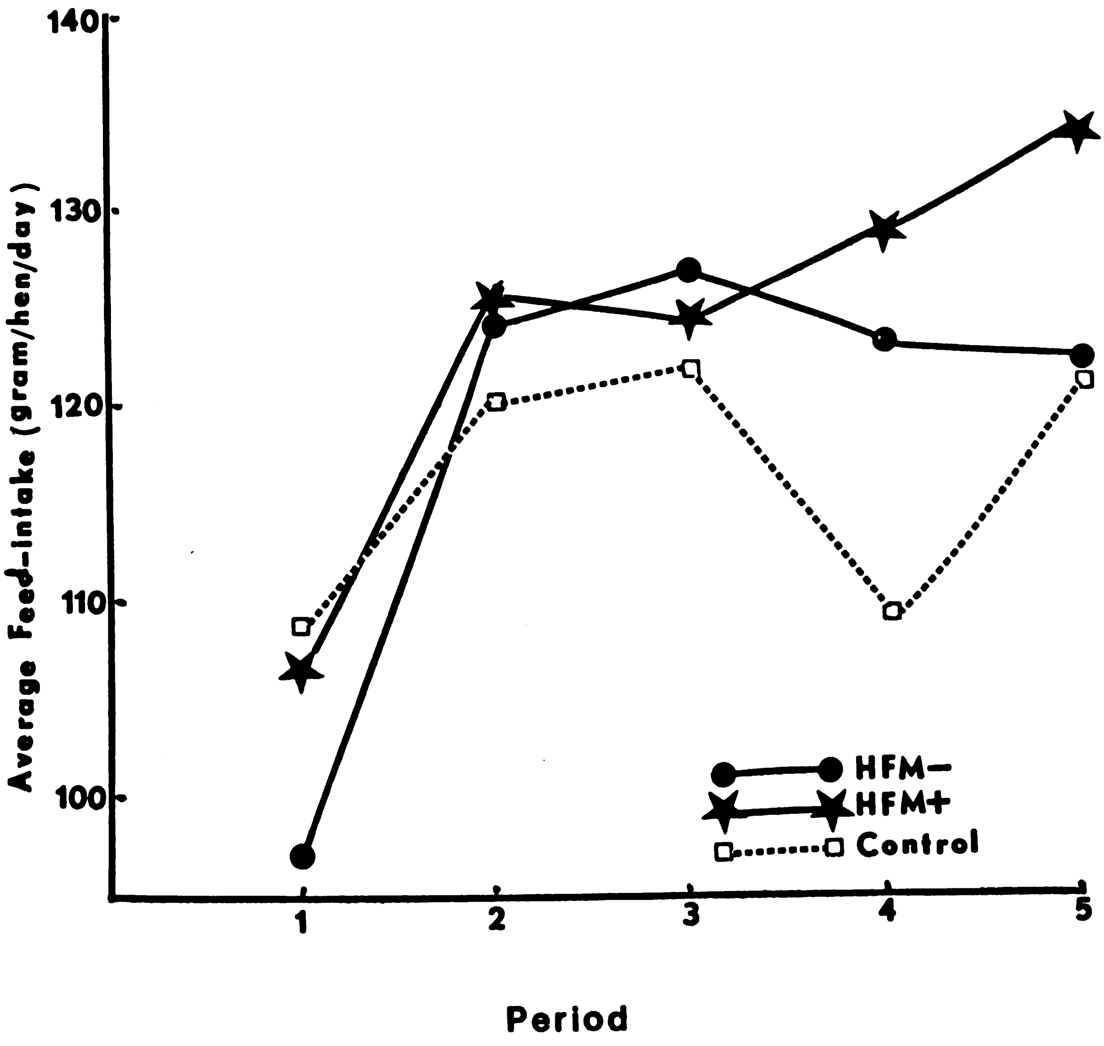

Figure 8. Feed-Intake Response to Period.

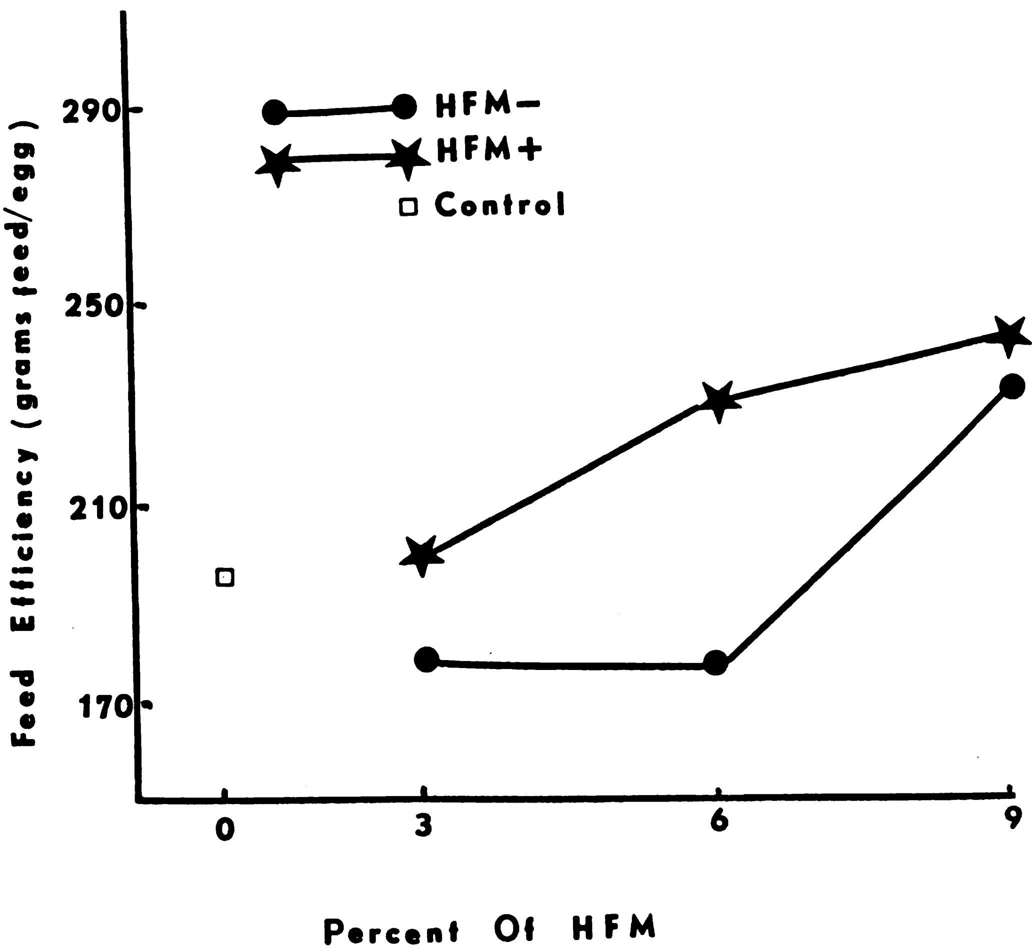

Figure 9. Feed Efficiency Response by HFM.

for feed efficiency are probably due to the diet ingredients and length of experiments which were different from the present experiment to Moran et al. (1969) and Van and Payne (1977) experiments.

There was a significant ($P < 0.05$) difference in feed efficiency by periods (Appendix, Table 17). Feed efficiency by periods is shown in Figure 10 and Table 12. The poorer efficiency during period one than during period two was probably due to the fact that the hens were housed at 20 weeks of age and many were reaching sexual maturity during the first period. As was pointed out earlier, the peak of production for all treated groups was achieved in the second period and for the control group in the third period.

Haugh Units

The Haugh units were high (83.0+) and they were not signifcantly affected by the addition of feather meal (Appendix, Table 18; and Figure 11). There was a significant difference (P 0.05) in Haugh units by periods (Appendix, Table 18). Figure 12 shows the variation of Haugh units in different periods. The average Haugh units in the control, supplemented and unsupplemented groups is shown in Table 13. The addition of feather meal to the diet of laying hens did not have any significant effect on egg quality.

Mortality

There was no significant difference ($P < 0.05$) in mortality due to treatment or period (Appendix, Table 19). In Figure 13, mortality

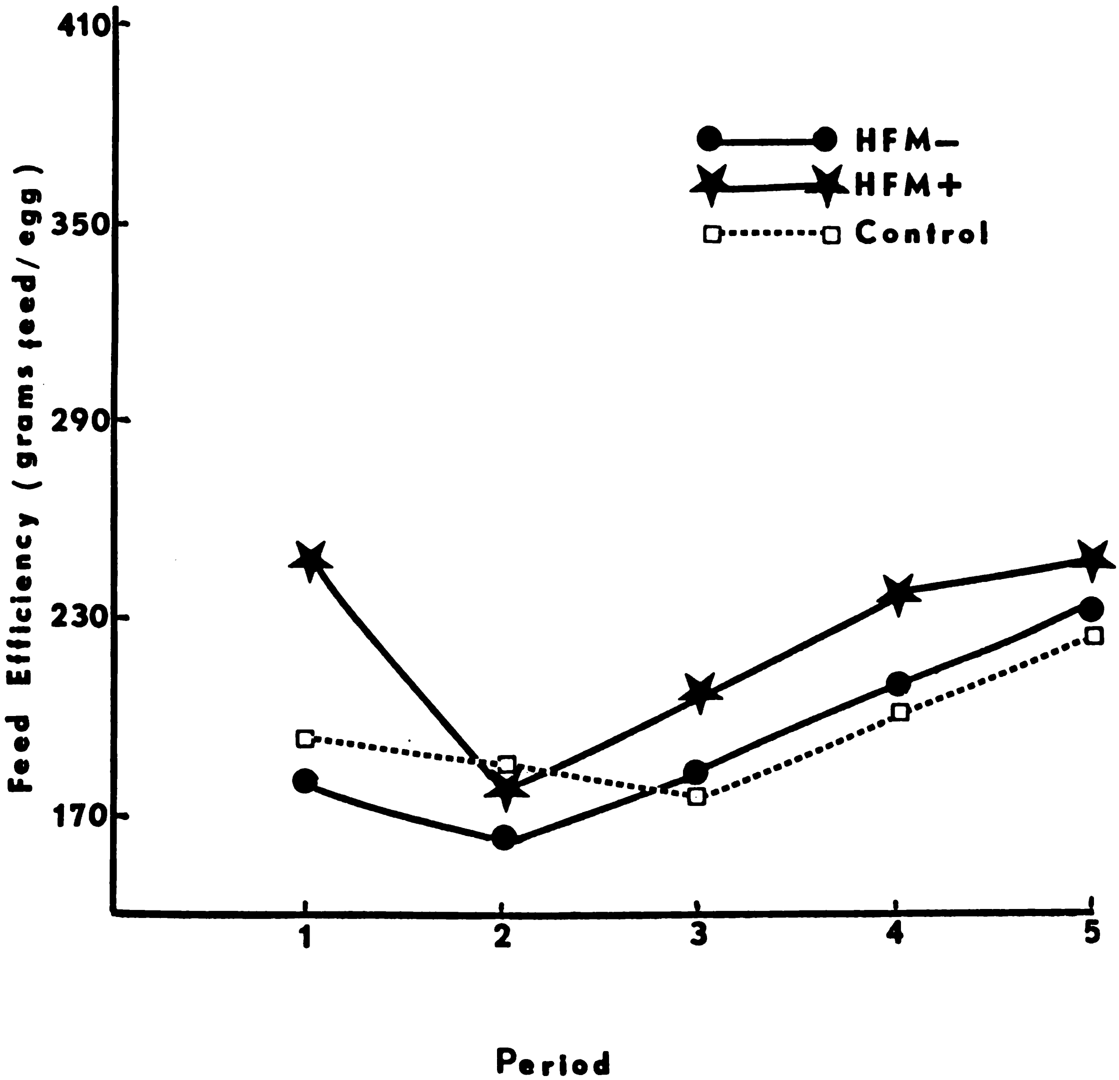

Figure 10. Feed Efficiency Response by Period.

Table 12

The Average Feed Efficiency in the Control Group,
Supplemented and Unsupplemented Groups
(grams of feed/egg)

	Periods[a]				
Treatments	1st	2nd	3rd	4th	5th
Control[b]	192.3	179.9	176.9	202.3	228.0
Average of supplemented[c]	250.5	176.8	206.5	239.3	246.6
Average of unsupplemented[c]	182.2	165.8	184.4	213.7	232.4

[a]Each period is 28 days.

[b]Each datum in this row is the average of 24 birds feed efficiency.

[c]Each datum in these rows is the average of 72 birds feed efficiency.

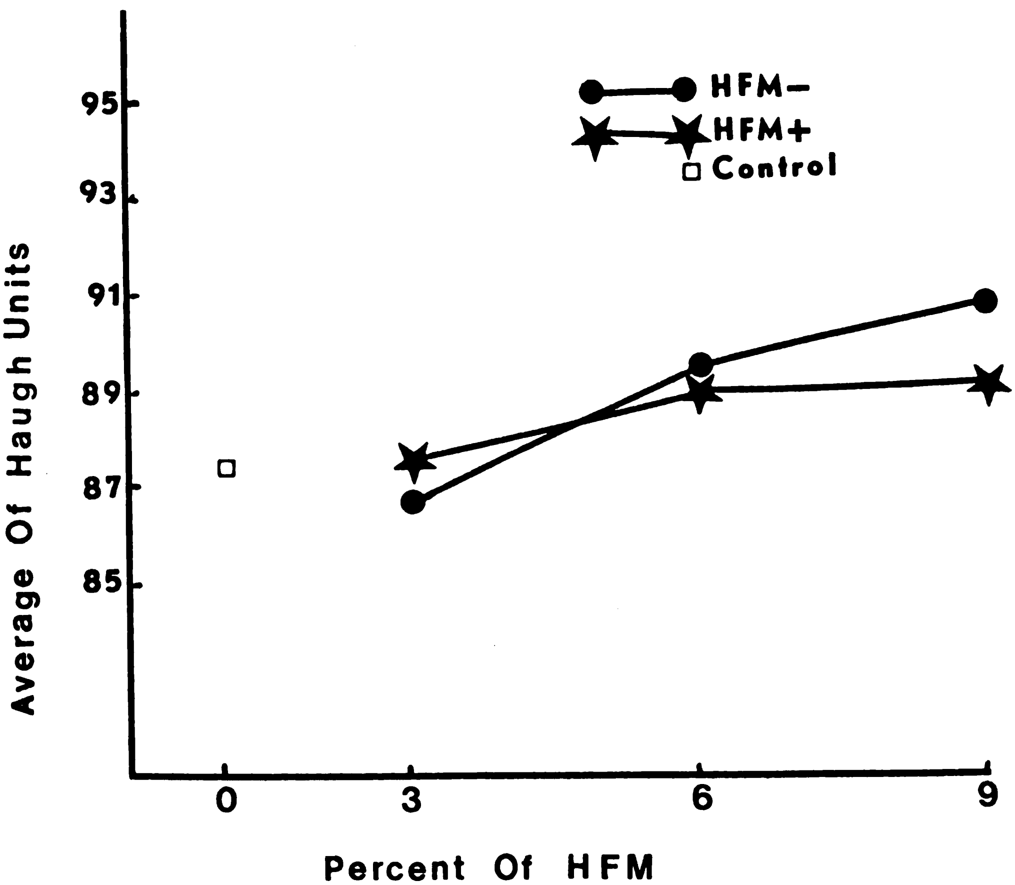

Figure 11. Haugh Units Response by HFM.

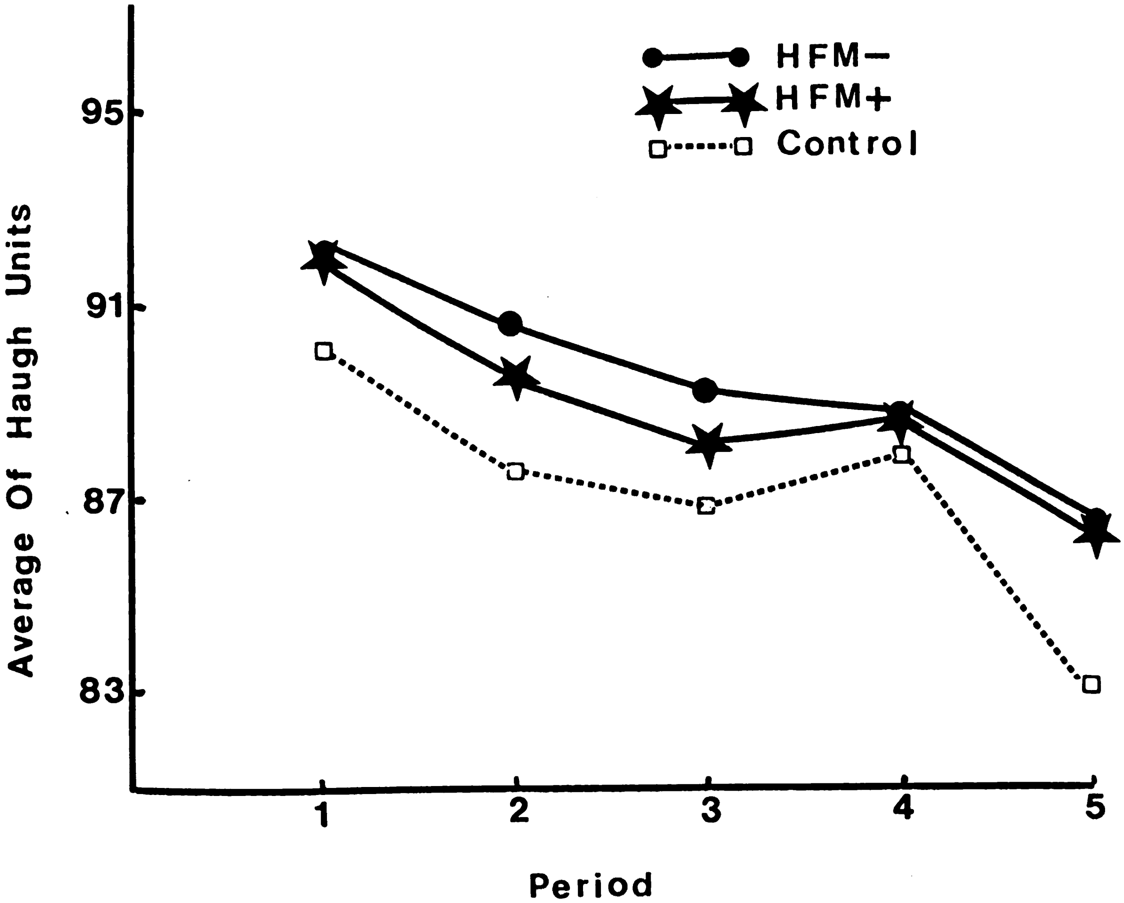

Figure 12. Haugh Units Response by Period.

Table 13

The Average of Haugh Units in the Control Group, Supplemented and Unsupplemented Groups

Treatments	Periods[a]				
	1st	2nd	3rd	4th	5th
Control[b]	90.2	87.6	86.9	88.4	83.03
Average of supplemented[c]	92.0	89.4	88.1	87.7	86.2
Average of unsupplemented[c]	92.0	90.6	89.1	87.3	86.3

[a]Each period is 28 days.

[b]Each datum is the average of 72 eggs Haugh units.

[c]Each datum in these rows is the average of 216 eggs Haugh units.

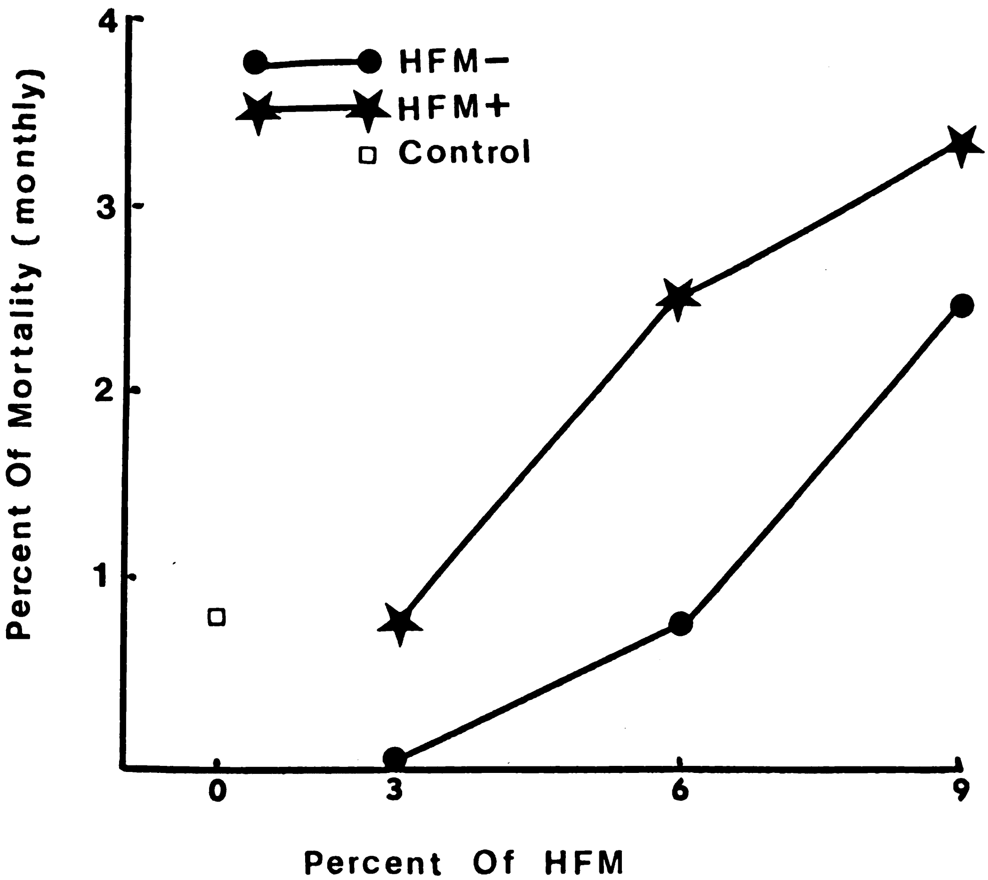

Figure 13. Effect of Treatment on Mortality.

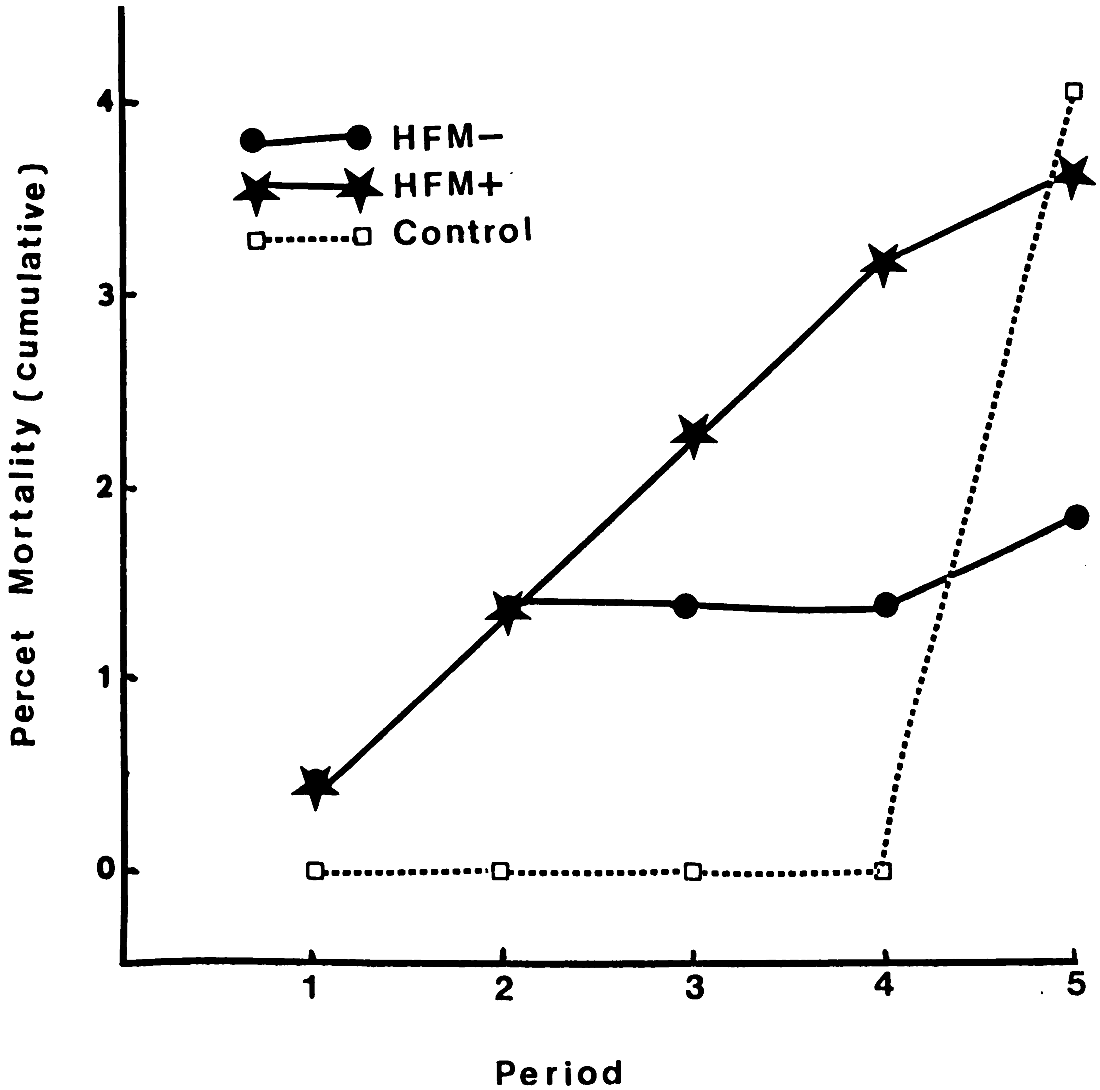

Figure 14. Mortality Response by Period.

for treatments is shown; whereas, in Figure 14 mortality is shown by periods.

Weight Gain

There was a significant difference ($P < 0.05$) between treatments in average weight gain per bird over the 140 day period of the experiment (Appendix, Table 20). Weight gain response to treatments is shown in Figure 15.

General Discussion

The birds that received the diet that contained 3 percent hydrolyzed feather meal with no supplementation of amino acids (HFM-) had a significantly higher ($P < 0.05$) percentage egg production and egg weight than those birds fed on the diet that contained 9 percent HFM-. The necessity for supplementing layer's rations containing HFM with methionine and lysine became clear and confirms the work Moran et al. (1969) and Van and Payne (1977). There was no significant difference ($P < 0.05$) between control and all treated birds in feed consumption and feed efficiency. Moran et al. (1969) showed an increase in feed consumption when methionine was supplemented in diets of laying hens; whereas this was not found in the present experiment. Level of protein and age of the birds used may explain this difference.

Weight gain was different among treatments and mortality occurred at random in all groups.

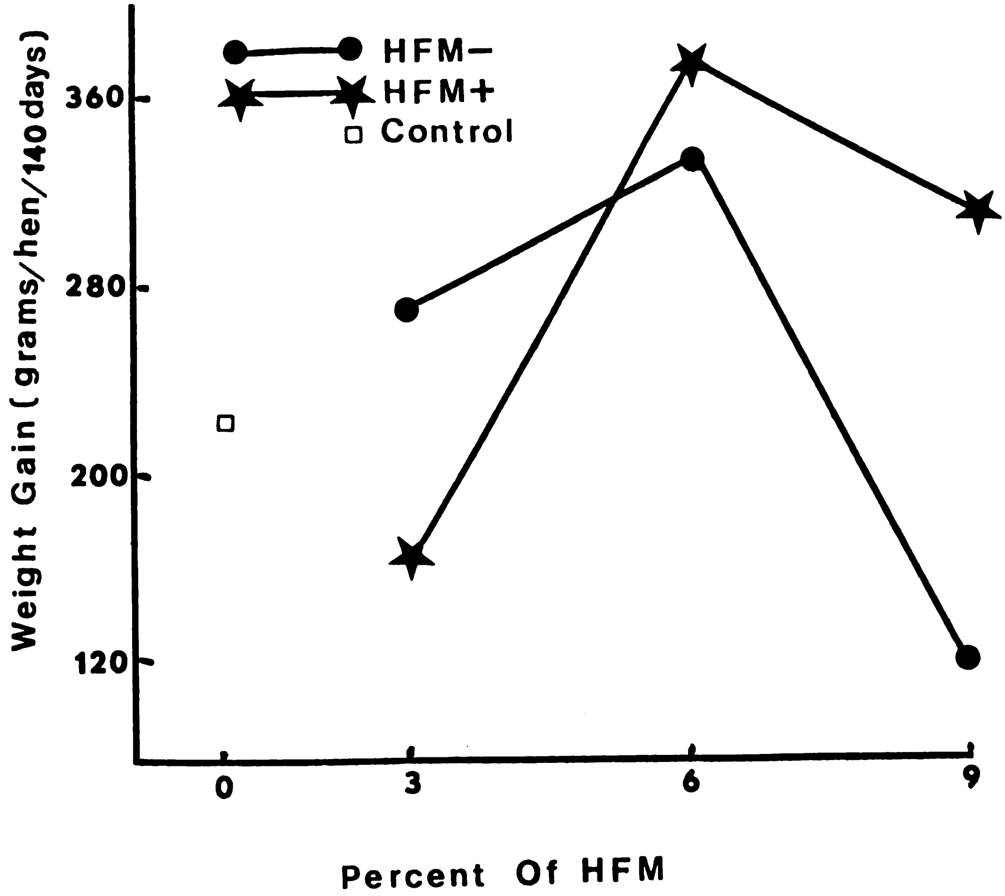

Figure 15. Weight Gain Response by Treatments.

The Effect of Feather Meal as a Source of Protein on the Production of Laying Hens

Summary

This experiment was conducted to determine the effect of different levels of added commercial hydrolyzed feather meal (HFM) on the production of laying hens. Feather meal was included in the diet at the level of 3, 6 or 9 percent with and without supplementation of amino acids (methionine and lysine). One corn-soybean type diet was prepared, without addition of feather meal, as a control diet. All rations were isocaloric and isonitrogenous.

One hundred sixty-eight female birds, 20 weeks of age, were divided into 21 groups of eight birds each on the basis of their weight. The experimental birds were randomly housed in individual laying cages. Feed and water was provided ad libitum and duration of experiment was five periods of 28 days each. The birds were weighed individually at the beginning and at the end of the experiment. Eggs were collected and recorded every day; also, in the last three consecutive days of each period, the eggs were weighed and Haugh units were measured. Feed consumption was determined for each period and mortality was recorded.

There was a significant difference ($P < 0.05$) between birds that received the 3 and 9 percent HFM- (hydrolyzed feather meal with no supplementation of amino acids) rations in the percentage of production and egg weight with a linear decrease from 3 to 9 percent. There was no significant difference ($P > 0.05$) between the control

group and the birds that received the 3, 6 and 9 percent HFM+ (hydrolyzed feather meal with supplementation of amino acid) rations in egg production and egg weight. Egg weight in all treated and control groups was significantly increased ($P < 0.05$) by the age of the birds. Feed-intake, feed conversion Haugh units and mortality did not significantly change ($P > 0.05$) between the control and treated groups. All the above factors except mortality significantly changed ($P < 0.05$) by periods in various treatments. The overall weight gain in 140 days of the experiment was significantly different between the various treatments.

On the basis of this study it can be concluded that the amino acid requirement of laying hens can be met when up to 6 percent hydrolyzed feather meal is included in a corn-soybean type diet. Inclusion of 9 percent HFM in the diet has deleterious effects on production and egg weight if the diet is not supplemented with lysine and methionine.

APPENDIX

Table 14

Analysis of Variance by the Use of Split-Plot Repeat Measurement for Egg Production (%)

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Treatment	6	377.22	62.87	1.94	0.05
B vs. D[a]	1	58.6	--	1.81	0.05
E vs. G[b]	1	241.3	--	7.46	< 0.05*
B + D vs. C	1	26.7	--	0.826	0.05
E + G vs. F	1	35.3	--	1.09	0.05
Control vs. treated	1	1.22	--	0.038	0.05
Supplemented vs. unsupplemented	1	13.75	--	0.425	0.05
Error a	14	452.662	32.33	--	--
Period	4	489.425	122.356	26.848	< 0.05*
Period by treatment	24	114.845	4.785	1.05	0.05
Error b	56	255.212	4.56	--	--
Total	104	2066.234			

*These contrasts are significantly different.

[a]B, C and D diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, with amino acid supplementation.

[b]E, F and G diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, without supplementation of amino acid.

Table 15

Analysis of Variance by the Use of Split-Plot Repeat Measurement for Egg Weight (grams/egg)

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Treatment	6	129.59	21.599	2.356	0.05
B vs. D[a]	1	2.44	--	0.266	0.05
E vs. G[b]	1	67.17	--	7.330	< 0.05*
B + D vs. C	1	8.76	--	0.955	0.05
E + G vs. F	1	4.18	--	0.456	0.05
Control vs. treated	1	1.38	--	0.150	0.05
Supplemented vs. unsupplemented	1	46.46	--	5.068	< 0.05*
Error a	14	128.34	9.167	--	--
Period	4	620.898	155.224	126.93	< 0.05*
Period by treatment	24	40.597	1.692	1.383	0.05
Error b	56	68.48	1.22	--	--
Total	104	1118.296			

*These contrasts are significantly different.

[a]B, C and D diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, with supplementation of amino acid.

[b]E, F and G diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively without supplementation of amino acid.

Table 16

Analysis of Variance by the Use of Split-Plot Repeat Measurement for Feed Consumption (kilograms/period)

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Treatment	6	1.120	0.1867	0.904	0.05
B vs. D[a]	1	0.0136	--	0.065	0.05
E vs. G[b]	1	0.380	--	1.840	0.05
B + D vs. C	1	0.011	--	0.053	0.05
E + G vs. F	1	0.014	--	0.067	0.05
Control vs. treated	1	0.253	--	1.225	0.05
Supplemented vs. unsupplemented	1	0.46	--	2.22	0.05
Error a	14	2.89	0.2065	--	--
Period	4	6.339	1.585	31.41	< 0.05*
Period by treatment	24	2.254	0.094	1.86	0.05
Error b	56	2.825	0.050	--	--
Total	104	16.559			

*This contrast is significantly different.

[a]B, C and D diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, with supplementation of amino acid.

[b]E, F and G diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, without supplementation of amino acid.

Table 17

Analysis of Variance by the Use of Split-Plot
Repeat Measurement for Feed Conversion
(grams of feed/egg)

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Treatment	6	67062.3	11177.0	1.256	0.05
B vs. D[a]	1	15833.2	--	1.779	0.05
E vs. G[b]	1	23129.6	--	2.660	0.05
B + D vs. C	1	752.3	--	0.084	0.05
E + G vs. F	1	993.14	--	0.111	0.05
Control vs. treated	1	17411.14	--	1.950	0.05
Supplemented vs. unsupplemented	1	17787.26	--	2.009	0.05
Error a	14	124592.97	--	--	--
Period	4	55186.5	13796.6	8.530	< 0.05*
Treatment by period	24	40940.65	1705.86	1.050	0.05
Error b	56	90523.98	1617.42	--	--
Total	104	453319.9			

*This contrast is significantly different.

[a]B, C and D diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, with supplementation of amino acid.

[b]E, F and G diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, without supplementation of amino acid.

Table 18

Analysis of Variance by the Use of Split-Plot, Repeat Measurement for Haugh Units

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Treatment	6	552.30	92.05	1.43	0.05
B vs. D[a]	1	16.72	--	0.259	0.05
E vs. G[b]	1	137.80	--	0.140	0.05
B + D vs. C	1	4.62	--	0.072	0.05
E + G vs. F	1	4.58	--	0.071	0.05
Control vs. treated	1	8.11	--	0.126	0.05
Supplemented vs. unsupplemented	1	4.40	--	0.069	0.05
Error a	14	901.29	64.38	--	--
Period	4	1070.30	267.58	3.480	< 0.05*
Period by treatment	24	1883.40	78.47	1.020	0.05
Error b	56	4301.7	76.90	--	--
Total	104	8885.22			

*This contrast is significantly different.

[a]B, C and D diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, with supplementation of amino acid.

[b]E, F and G diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, without supplementation of amino acid.

Table 19

Analysis of Variance by the Use of Split-Plot Repeat Measurement for Mortality

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Treatment	6	0.857	0.1428	0.940	0.05
B vs. D[a]	1	0.300	--	1.969	0.05
E vs. G[b]	1	0.300	--	1.970	0.05
B + D vs. C	1	0.011	--	0.072	0.05
E + G vs. F	1	0.011	--	0.072	0.05
Control vs. treated	1	0.057	--	0.374	0.05
Supplemented vs. unsupplemented	1	0.177	--	1.160	0.05
Error a	14	2.133	0.1524	--	--
Period	4	0.1524	0.038	0.271	0.05
Period by treatment	24	2.381	0.0992	0.706	0.05
Error b	56	7.866	0.1405	--	--
Total	104	14.2454			

No contrasts are significantly different.

[a]B, C and D diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, with supplementation of amino acid.

[b]E, F and G diets are 3, 6 and 9 percent hydrolyzed feather meal, respectively, without supplementation of amino acid.

Table 20

Analysis of Variance by the Use of Split-Plot Repeat Measurement for Average of Weight Gain

Source of Variation	df	Sum of Square	Mean Square	F	P > F
Main effect	6	123017.7	20502.9	3.276	< 0.05*
Treatment	6	123017.7	20502.9	3.276	< 0.05*
Explained	6	123017.7	20502.9	3.276	< 0.05*
Residual	14	87628.0	6259.1	--	--
Total	20	210645.8	10532.3		

*Significantly different.

LITERATURE CITED

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