THE RELATIONSHIP OF PROTEIN, ENERGY AND VOLUME INTAKE IN EGG-TYPE CHICKENS DURING THE GROWING PERIOD TO SUBSEQUENT LAYING HOUSE PERFORMANCE

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INTRODUCTION

The question as to which method of feeding replacement pullets is most desirable has been debated for many years. Some poultrymen have advocated rearing pullets on a full feeding program, while others are enthusiastic about a restricted feeding program. The results of current research in which these two systems are compared are inconclusive and contradictory. The basic problem encountered in these research studies has been to provide a suitable range of nutrient intakes to pullets during the growing period and to measure the effect of range of nutrient intakes upon subsequent laying house performance.

Gleaves (1961), Gleaves *et al*. (1963a) and Gleaves (1965) reported data from a series of experiments in which gradations in the dietary volume of rations fed *ad libitum* were used to control the nutrient intake of laying hens. Non-nutritive polyethylene fluff was used as the volume control ingredient. In addition, washed blow sand was used to control dietary weight. Through the use of these techniques, it was possible to obtain predetermined gradations in the daily nutrient intake of protein and energy and to study their effects upon laying house performance.

In the study reported in this thesis, the method used by Gleaves *et al*. (1963a) and Gleaves (1965) was applied to the growing of replacement pullets. In this way it was possible to regulate or control the nutrient intake of growing pullets and to obtain graded intake levels of protein, energy and feed volume. Data were obtained on the relationship of a number of intake levels of protein, energy and feed volume, both individually and in combinations, to certain aspects of the subsequent reproductive performance of pullet replacements.

The goal of pullet growing is to obtain maximum laying house performance with the lowest practical rearing costs. This is especially important today with specialized pullet growing operations and small profit margins.

In view of the current situation, the objectives selected for this study were to: (1) study nutrient intake during the growing period as it is related to dietary protein level, dietary energy level and dietary volume level; and (2) determine the effects of different nutrient intakes during the growing period upon subsequent laying house performance, including egg production, egg weight, livability and body weight gain or loss.

REVIEW OF LITERATURE

Work was started as early as 1937 on a program of restricting feed intake for growing replacement pullets. The following observations were made with pullets which were fed less than full feed from 8 to 24 weeks of age: (1) sexual maturity was delayed, as measured by the onset of egg production; (2) the number of small eggs produced was reduced; (3) livability in the laying house was increased; and (5) there was a 35 to 50 percent saving in the amount of feed consumed. These early claims were widely publicized by the popular press despite the fact that very little scientific research had been done to validate them (Bruins, 1958; Ewing, 1963).

In an effort to determine the effects of feed restriction on growing replacement pullets, three basic methods of restricting feed or nutrient intake were developed and have been the subject of extensive research studies. The first method is known as limited feeding or quantitative restriction. It can be divided into three categories: (a) limiting the time during the day that feed is available; (b) withholding the feed every 3rd, 5th or 7th day; and (c) limiting the poundage of feed fed to a percentage of the amount consumed by full-fed controls. The second method involves the use of high levels of fiber in the ration. High fiber diets are fed *ad libitum*, but due to the low nutrient density of these diets, restriction of nutrient intake occurs. The third method involves the restriction of protein intake and is accomplished by widening the calorie-protein ratio.

Methods of Restriction

Limited Feeding or Quantitative Restriction

Limited Daily Feeding Time: Heuser et al. (1945) limited feed intake by keeping the feeders closed until noon each day. The birds soon adjusted to feed being available only in the afternoon; consequently, this method resulted in only a 3 to 8 percent reduction in feed consumption. This rate of restriction was apparently not severe enough to produce a significant difference when compared to full-fed birds.

Ringrose (1958) used techniques involving quantitative feed restriction in two experiments. In the first experiment, enough mash was placed in the feeders so that at the end of a daily four-hour morning feeding period the feeders were empty. In addition to mash, the growing ration consisted of 25 percent of oats which was fed at 4 p.m. This feeding regimen was followed during the growing period from the 7th to the 20th week. In the second experiment, the amount of mash placed in the feeders was increased so that at the end of the four-hour feeding period mash was left in the feeders. At this time the feeders were removed from the pens. This procedure was adopted because it made the mechanics of handling the experiment simpler and insured availability of feed for the four-hour period. Ringrose (1958) found that feed restriction on a time basis as studied in these two experiments resulted in only a moderate restriction in feed intake, and after the birds were 16 weeks of age very little restriction in feed intake was evident.

Tomhave (1958) reported two experiments in which feeding time was restricted during the growing period from the 9th to the 23rd week. In the first experiment, feed was placed in the feeders at 8 a.m. in amounts to last the birds to 12 o'clock noon. This resulted in a feed consumption level of from 89 to 93 percent of that consumed by full-fed birds. In experiment 2, the feeders were closed from 10 a.m. to 4 p.m. daily in an effort to produce more drastic feed restriction. However, the restricted-fed birds consumed 95 percent as much as the full-fed controls.

Heuser _et al_. (1945), Ringrose (1958) and Tomhave (1958) concluded independently that when growing pullets are restricted in the time that feed is available to them, they soon adjust themselves to the schedule of feeding. In so doing, they consume a sufficient quantity of feed in a shorter period of time, thus meeting their feed requirements for normal growth. Tomhave (1958) further concluded that a slight saving in feed during the growing period is the only consistent benefit derived from feed restriction when the birds have access to the feed only during certain hours of the day. Thus, it is doubtful if this method of feed restriction compensates for the extra labor involved. On the other hand, Clark _et al_. (1962) found that by restricting the feeding time to two hours a day during a five to seven day period each week, feed consumption was reduced about 24 percent during the growing period.

Withholding Feed on Alternate Days: Limited feeding as used by Singsen *et al*. (1961) involves withholding all feed every 3rd, 5th or 7th day, depending upon the severity of restriction desired. In a review of restricted feeding, Patrick (1962) referred to this method of feed restriction as the "stop and go" system. Kent (1955) recommended a similar method of restricting feed intake in which five pounds of pellets were fed per 100 birds five mornings a week plus all the oats they could eat in one or two hours. On two days a week (1st and 4th days) the birds were fed nothing in the morning. Every afternoon the birds were given all the oats they could eat in 10 minutes. This system was reported to restrict birds to 70 percent of what full-fed growing birds consumed. Bruins (1958) reported that many commercial poultrymen were unable to follow such a program because of inexperienced labor or insufficient equipment.

Limiting Feed on a Percentage Basis: A third method of limiting feed intake is to restrict growing pullets to a certain percentage of the feed consumed by full-fed control birds. This system has been studied by many researchers. Any desired degree in severity of restriction can be obtained with this system by lowering the percentage of feed fed to the restricted birds. Most workers have used and now recommend a 20 to 30 percent restriction in feed consumption from approximately 8 or 10 weeks of age to approximately 20 to 23 weeks of age.

In following this method, Milby and Sherwood (1956) used a 15 percent restriction in feed consumption on pullets grown in confinement and a 30 percent restriction in feed consumption on range-reared pullets. Ringrose (1958) found that restricting the feed during the growing period to 20 percent or more on a poundage basis reduced body weight and delayed sexual maturity. Tomhave (1958) reported that an actual restriction in the amount of feed consumed by a pullet is a more effective way of restricting feed intake than is limiting the time that feed is available to the birds during the day. The former procedure results in more of the benefits of feed restriction. Bruckner and Hill (1959) reported that satisfactory pullets could be reared using a 20 to 30 percent restriction of diet intake. Hollands and Gowe (1961) imposed a 37.5 percent level of feed restriction on White Leghorn pullets from the 3rd to the 8th week of age, and a 32.5 percent level of feed restriction from the 8th to the 21st week of age. Honegger Farms Co., Inc., as reported in Honegger Fax, (Anonymous, 1963), used a 27 percent restriction of feed from the 8th to the 21st week of age as compared to full-fed controls. Bruins (1958) and Singsen (1955) reported that limiting feed on a percentage basis is the most economical method of growing replacement pullets.

Restricting Nutrient Intake With Fiber

Restriction of nutrient intake may be achieved by feeding rations which contain 5 to 20 percent of added fiber. High fiber rations are fed to birds *ad libitum*; but due to the low nutrient density of these rations, birds cannot eat enough feed to satisfy their nutrient intake requirements.

Isaacks *et al*. (1960) reported that with meat-type pullets a restriction in nutrient intake similar to that obtained by limiting feed intake could be accomplished by varying the levels of fiber in the diet. However, it was pointed out that by limiting the intake of a high efficiency diet on a percentage basis an approximate savings of 25 percent in feed could be made during the growing period; whereas, restricting nutrient intake by adding 15 to 20 percent of fiber resulted in a 39 to 49 percent increase in total feed consumption.

Quisenberry (1958) found that egg-type pullets gave approximately the same results as did meat-type birds when nutrient intake was restricted through the use of high fiber diets. However, he questioned the wisdom of going from a high efficiency rearing ration, which grows a pullet to 21 weeks of age on approximately 16 pounds of feed, to a high fiber ration that requires 30 to 33 pounds of feed to grow a pullet to the same age.

Ringrose (1959) pointed out that restricting the nutrient intake of growing pullets by feeding high fiber rations can increase feed costs. Deaton and Quisenberry (1963) reported high fiber diets to be more expensive than conventional diets when the total amount of feed consumed by the birds was considered. In contrast, Bruins (1958) reported that birds fed high fiber rations can be competitive, price-wise, with birds full-fed on conventional commercial rations and also give the additional benefits of restricted fed birds.

Restriction of Protein Intake

Limiting protein intake was advanced by Harms (1962) as a third method of feed restriction. The protein intake of growing pullets is limited by feeding a diet having a wide calorie-protein ratio. However, Harms (1962) believes that the best performing commercial egg-type pullets can be produced by using high energy-high protein diets. Clark et al. (1962) fed whole grain and a calcium supplement as the only feed to growing pullets on grass or clover range. As this type of diet would have a wide calorie-protein ratio, it would appear to be a modification of limited protein intake as reported by Harms (1962). Clark et al. (1962) referred to this grain-mineral diet for growing pullets on range as qualitative restriction and reported it to produce essentially the same effects as quantitative restriction. Platt (1944), who fed only grain and minerals to growing pullets on range, found that pullets were retarded in a manner similar to those reared on a limited feeding program.

Periods of Restriction

It appears that the severity of restriction is determined by: (1) the length of the period during which feed or nutrient intake restriction occurs; (2) the time during the growing period that the feed or nutrient intake restriction is imposed; and (3) the percent or amounts of nutrients withheld from the birds during the restriction period. These factors appear to play a vital role in producing the effects brought about by the restriction of feed or nutrient intake.

Watts (1955) observed that very good nutritional practices should be followed during the initial four to eight weeks of the chick's life, since this is a critical period. He reported that the performance efficiency of pullets was reduced when the intake of nutrients was limited during the first month of the chick's life, either by limiting the actual amount eaten or by changing the composition of the ration.

In an effort to study time of restriction, length of restriction and severity of restriction, Gardner and MacIntyre (1962) limited feed intake for growing pullets to 50, 60 and 70 percent of the amount consumed concurrently by full-fed controls. Length of the restriction periods ranged from 3 weeks to 17 weeks. This restriction was imposed at various intervals during the growing period. Restriction periods started as early as the fifth week of the growing period and some lasted until the birds were 22 weeks of age. They found a direct relationship between the duration and degree of restriction and the amount of body weight reduction. With restriction periods of either four or eight weeks, there was a greater reduction in body weight when the restriction was imposed at an older age. They also found that the length of time required to attain sexual maturity, as measured by the number of days to reach 50 percent production, decreased as the length of the restriction period decreased, regardless of the degree of restriction which was imposed in this study.

Pullets which were restricted during the growing period produced a greater percentage of medium and large size eggs during the first few months of production. However, the magnitude of the increased size appeared to depend upon the length of the restriction period. As the length of the restriction period decreased, the percentage of large and medium eggs also decreased. Restricted feeding had no significant effect on egg weights. However, there was a trend toward increased egg weight with treatments which had the longest delay in sexual maturity.

Fuller and Dunahoo (1962) restricted the feed intake of White Leghorn pullets for the following time intervals during the growing period: none, 6th through 12th week, 6th through 18th week, 6th through 24th week, and 12th through 24th week. Feed was limited during all restriction periods to the average intake at six weeks of age (9 pounds per 100 birds per day). Economic characteristics were observed for three years of egg production.

While all periods of feed restriction significantly retarded growth rate, recovery was rapid after the birds were placed on full feed. Growth curves during recovery periods following feed restriction were steeper in slope than normal growth curves of full-fed birds at any given time during the growing period. Where feed restriction was terminated by the 12th week of age, the group recovered rapidly and outweighed the full-fed controls at 24 weeks of age. Where birds were on continuous feed restriction from the 6th to the 24th week of age, mature body weight never equalled that of the controls during the entire three years of egg production which followed.

Limiting feed intake delayed sexual maturity of pullets up to as much as four weeks, depending upon the duration of the restriction. When the egg production period was calculated beginning at 20 weeks of age for all treatments, restricting the nutrient intake of pullets from 6 to 24 weeks of age improved egg production. However, it was statistically significant only during the third year. On the other hand, when egg production was calculated beginning with the date the first egg was laid for each treatment, the pullets restricted in nutrient intake to the 24th week of age produced significantly more eggs during the first and third years of production.

The effect of the restriction of nutrient intake on egg size was evidenced only by larger initial eggs for pullets that were restricted until they were 24 weeks of age. Fuller and Dunahoo (1962) also observed that the length of time of the restriction period did not affect egg size on any given calendar date after the first few weeks of production, nor the amount of feed required for pullets to reach sexual maturity. Birds that were restricted for periods of 12 or 18 weeks during the growing period required less feed per dozen eggs produced during the laying period.

MacIntyre and Gardner (1964) subjected White Leghorn pullets to 70 percent of the feed intake level consumed by full-fed control birds for the following intervals during the growing period: none, 5th through 21st week, 5th through 23rd week, 5th through 25th week, 5th through 27th week, and 5th through 29th week. They found that sexual maturity, as measured by the number of days required for pullets to reach a 50 percent level of egg production or peak production, was delayed progressively as the duration of the restriction period increased. Restricting feed intake until pullets were 27 or 29 weeks of age appeared to be detrimental to egg production, while feed restriction periods up to the 25th week of age gave a favorable effect on egg production. Feed efficiency during the growing and laying periods was higher, but not significantly so, for the restricted-fed birds with the exception of those restricted to the 29th week of age as compared to full-fed controls.

Effects of Feed or Nutrient Restriction

Other Species

In a review by McCay (1947), evidence was presented which indicates that feed restriction during the growing period may increase longevity in rats, mice, dogs and humans. A suggested explanation for the increased longevity is that the restricted individuals show greater resistance to the diseases common at old age, particularly those of a cancerous type. Lane and Dickie (1958) found that severe obesity resulting from overeating in mice, whose genetic constitutions favor overeating, greatly shortens their life span. Ingle et al. (1937) studied the effects of feed restriction on the Cladocera (water flea) species. He found that restricted-fed individuals lived significantly longer than those which were full-fed. Reid (1960) reported that cows reared on a high plane of nutrition exhibited a definite tendency to encounter breeding difficulties during adulthood and consequently to have a shorter productive life than cows reared on a low intake of energy. Silberberg and Silberberg (1955) concluded that somewhere between the extremes of undernourishment and dietary enrichments lie the regimens that are optimal for longevity.

Not only does restricted feeding appear to increase longevity, but it is also reported to increase reproductive efficiency. Self et al. (1953) studied the effect of full-feeding versus limited-feeding from weaning to slaughter on the reproductive performance of gilts. He found that full-feeding of gilts after puberty resulted in 25 percent fewer embryos than corresponding restricted-fed gilts, regardless of the method of prepubertal feeding. Ingle et al. (1937) found that groups of water fleas which were restricted in feed consumption produced the same number of young, although later in life, than did full-fed control groups.

Reid (1960) reported that a reduced intake of energy during the growing period greatly delays the onset of puberty in cattle, has little effect on the age at puberty in swine, and hastens the breeding season in sheep. In both the pig and sheep, feeding a low level of nutrition after conception is conducive to a high rate of embryonic survival.

James and McCay (1944) studied restriction of nutrient intake in growing dogs and found that dogs which were retarded in growth due to limited feed intake exhibited low heart and breathing rates. Ingle et al. (1937) found that limited-fed water fleas exhibited a lower metabolic rate than those receiving unlimited food. He also found decreased heart rates in restricted-fed fleas. These heart rates did not return to normal when the fleas were placed on full feed.

Growing Pullets

Since 1937 when early claims were made for restricted feeding of growing pullets, several experiments have been conducted to determine the effects of restricting feed or nutrient intake upon subsequent laying house performance. Ewing (1963) made the following statement: "Considering the amount of research that has been reported on restricted feeding of replacement pullets, we ought to have all the answers -- but this is far from the case. On the surface, consistent results are the exception, rather than the rule......" Despite the inconsistent results, there are some points of general agreement among research workers concerning the effects of restricting feed or nutrient intake to growing pullets.

Physiological Changes: It appears that restricting the feed intake of pullets during the growing period produces certain physiological effects. Fuller and Dunahoo (1962) reported that restricting feed intake during the growing period resulted in a lower basal metabolic rate as measured by O_2 consumption. The lower basal metabolic rate appeared to persist for six months after feed restriction was discontinued. Gowe *et al*. (1960) showed that when feed restriction was imposed on growing pullets it caused a decrease in the heart rate and the blood pressure at the end of the restriction period. These workers also found that feed restriction caused pullets to have relatively larger adrenals, pituitaries and gizzards (per gram of body weight). It appears that additional research work is needed to determine more fully the physiological effects produced by imposing a restriction of feed or nutrient intake on growing pullets.

Body Weight: It is generally agreed among research workers that body weight or size at housing time is decreased by restricting the feed or nutrient intake of pullets during the growing period. However, it appears that when restricted-fed birds are placed on full feed, they gain more rapidly than full-fed birds and usually attain a body weight equal or nearly equal to full-fed controls after a few months of *ad libitum* feeding. Whether or not restricted-fed birds attain body weight equal to controls appears to depend upon the severity of the restriction imposed.

Schneider *et al.* (1955) found that restricted feeding was effective in retarding growth throughout the period of restriction. However, after four weeks of full feeding, pullets reared on a restricted feeding program had body weights equal to full-fed birds. Watts (1955) observed that pullets reared on limited feeding systems weighed approximately one-half pound less than did pullets which were full-fed until they were placed in the laying house. There was no significant difference in the body weight of the two groups after they were full-fed for three months. Isaacks *et al.* (1960) reported that restricted feeding retarded growth during the rearing period, but had no effect on body weight at 57 weeks of age. In contrast, MacIntyre and Gardner (1964) used a feeding method which severely restricted feed intake, and found that the decrease in body size caused by restricting feed intake to growing pullets carried through to the final body weight at the end of 11 months of egg production. At the Texas Experiment Station, Deaton and Quisenberry (1963) obtained data in support of these findings.

Harms (1962) observed that restricting the nutrient intake of growing pullets retarded body weight. Nevertheless, after limited-fed birds were placed on full feed for four weeks, their body weight was approximately equal to that of the full-fed groups. Harms (1962) also noted that an 18-gram difference in body weight at 20 or 21 weeks of age resulted in a one-day difference in the age of the pullet when the first egg was laid.

Sexual Maturity: The decrease in body weight or size typical of restricted-fed pullets is also closely coupled with delayed sexual maturity. The degree to which body size is decreased and sexual maturity is delayed is usually in direct proportion to the length and severity of the restriction period. Watts (1955) found that limiting feed intake during the growing period resulted in a delay of approximately 17 days in the onset of egg production. Hill (1962) observed that pullets which were restricted in feed intake during the growing period reached 50 percent egg production 11 to 28 days later than did full-fed birds. Milby and Sherwood (1956) found that restricted-fed pullets attained sexual maturity 10 to 15 days later than did full-fed control birds. That time of sexual maturity was delayed approximately two weeks by restricting the feed intake of growing pullets was found by Bruckner and Hill (1959). Tomhave (1958) observed that restricting feed intake to 75 percent of the feed consumed by full-fed pullets resulted in a delay of five to seven days in sexual maturity. Hollands and Gowe (1961) found that pullets reared on a limited feeding system were delayed approximately two weeks in reaching sexual maturity. MacIntyre and Gardner (1964) imposed a severe restriction on feed intake and reported that sexual maturity was delayed about 30 days, as measured by the age when the first egg was laid.

Mortality: Hollands and Gowe (1961) found that the mortality of limited-fed pullets was higher than that of full-fed pullets during the growing period. Mortality was observed to be lower with the limited-fed pullets throughout both the first and second egg production years. Bruckner and Hill (1959) found that rearing mortality tended to be higher and adult mortality to be lower when pullets are reared on a restricted level of feed intake. Fuller and Dunahoo (1962) observed during the period of limited feeding a higher than normal mortality rate in pullets which were severely restricted in nutrient intake. During the early part of the laying year the highest mortality was observed in the full-fed and less severely restricted groups.

In contrast, Schneider et al. (1955) found that mortality during the growing period was not affected by the feeding system. Adult mortality of slow-grown pullets, on the other hand, was significantly lower. Young et al. (1961) pointed out the possibility that limited-fed pullets might have a higher than average mortality rate during the growing period, particularly when a mild disease outbreak occurs. Isaacks et al. (1960) reported that the mortality rate of growing pullets was increased when the fiber level of the diet was high enough to reduce substantially the caloric intake.

Milby and Sherwood (1956) found that restricting feed intake of growing pullets had no effect on laying house mortality. Independent findings of Singsen (1955), Ringrose (1958), Quisenberry (1958) and Hill (1962) are in agreement with the findings of Milby and Sherwood (1956). To the contrary, Tomhave (1958) observed that the viability of pullets full-fed during the growing period was better during 311 days of egg production than that of pullets fed on a restricted basis. Research workers at Honegger Farms Co., Inc. (Anonymous, 1963) found that full-fed pullets had lower mortality rates in the laying house than did pullets reared on a restricted feeding program.

Egg Production: The fact that the rate of egg production is not increased by restricting the feed or nutrient intake to growing replacement pullets has been confirmed by a number of research workers. Watts (1955) found that egg production for a nine-month period was not significantly different for pullets reared on a limited feeding system as compared to full-fed control pullets. Harms (1962) observed that total egg production over a 336 day production period was not affected by the diet the pullets received during the growing period. Studies by Bruckner and Hill (1959) did not show consistent advantages for any single feeding program. They found that differences in the rate of egg production due to rearing nutrition were relatively small and highly variable.

Young *et al.* (1961) reported that poultrymen had no assurance that total egg production of pullets grown on a restricted feeding program would be increased. Milby and Sherwood (1956) observed that restricting feed intake during the growing period apparently had no real effect on subsequent egg production. Quisenberry (1958) reported that the rate of egg production showed no significant correlation with the rearing treatment of replacement pullets. Ringrose (1958), who studied restricted feeding of growing pullets over a six-year period, found that limited feeding did not result in a significant difference in subsequent egg production.

Tomhave (1958) observed no difference in egg production between full-fed and restricted-fed pullets during the first year of egg production. Berg and Bearse (1961) found that rate of lay was not affected by restricting the feed intake of pullets during the growing period. Hill (1962) reported that the average egg production per bird housed to 667 days of age was 253 for full-fed pullets as compared to 232-241 eggs for the restricted-fed birds. No significant difference was found by research workers at Honegger Farms, Co., Inc. (Anonymous, 1963) in yearly hen-day or hen-housed egg production between limited-fed pullets and full-fed controls. Therefore, on this basis the full-fed pullets produced the most eggs.

Contrary to the results found by the above workers, restricted-fed birds laid more eggs in the first production year than did full-fed controls in the experimental work of Hollands and Gowe (1961). Gardner and MacIntyre (1962) reported two experiments dealing with the restriction of feed intake for growing pullets. In the first experiment, they found a significant increase in egg production due to restricted feeding, while in the second experiment restricted feeding had no effect on egg production. Likewise, Isaacks et al. (1960) found that restriction of nutrient intake had no effect on egg production in the one experiment, but found egg production in another experiment to be considerably higher for restricted-fed groups of pullets.

Schneider et al. (1955) did not find a significant difference due to growing treatments in the total number of eggs laid. However, they observed a significant shift in the egg production pattern caused by growing treatments. Full-fed groups of pullets laid at a higher rate early in the laying period, while limited-fed pullets laid at a higher rate later in the production year. MacIntyre and Gardner (1964) found that the hen-day rate of egg production was significantly higher for full-fed pullets when measured from the date of sexual maturity, but was lower when measured on the basis of an equal period of laying time from the onset of sexual maturity of the retarded pullets.

Harms (1962) reported two experiments in which he observed that pullets reared on conventional high energy diets laid more eggs during the first two months in the laying house than did pullets grown on restrictive type diets. However, by the third month, the restricted-fed pullets had begun to lay at a rate equal to pullets grown on a full-feeding program. During the 4th to the 9th months of production, pullets which were grown on a restrictive type of grower ration laid at a slightly higher rate than did pullets grown on a full-feeding program. The egg production of the two groups equalized during the last three months of the production year. The difference in total egg production between the two groups for a 336-day laying period was not significant. However, the trend was for pullets which laid at an earlier age to lay at a slightly higher rate for the entire period. Walter and Aitken (1961) also observed a change in the egg production pattern of restricted-fed pullets. They found that slow-maturing, limited-fed pullets came into production later, but subsequently laid at a higher rate than did full-fed controls.

Egg Size: Young et al. (1961) reported that the most consistent improvement from restricted feeding of growing pullets is the increase in the number of medium and large size eggs laid during the production year. Watts (1955) found that the initial egg size of pullets reared on a restricted feeding program was one ounce larger per dozen than was the egg size produced by full-fed control pullets. However, no difference existed in egg size at any given age after the start of production. Sunde et al. (1954) observed that pullets which were delayed in sexual maturity by restriction of feed intake laid larger eggs initially. However, as the production year progressed, the egg weights of the two groups tended gradually to converge.

Schneider et al. (1955) found a significant difference in the number of hatching eggs produced by restricted-fed pullets as compared to full-fed control pullets. This could be partially accounted for by the fact that more eggs were laid late in the production year, after egg size had increased.

Fuller and Dunahoo (1962) found that restricting the feed intake of growing pullets resulted in larger initial eggs only if the pullets were restricted to 24 weeks of age. There was no significant difference in egg size on any given calendar date after the first few weeks of production. Research workers at Honegger Farms, Co., Inc. (Anonymous, 1963) found that restricted-fed pullets laid slightly larger eggs than did full-fed control pullets; however, the difference in egg size was not large enough to be significant.

In contrast to the above workers, Bruckner and Hill (1959) observed that when egg size was measured at the same chronological age, it was not affected by the previous rearing treatment. Harms (1962) reported that the kind of growing ration did not significantly affect egg weight at any given age. Ringrose (1958) found that restricting the feed or nutrient intake of growing pullets produced no significant effect on egg weight on any calendar date when compared to full-fed control pullets. Quisenberry (1958) observed no indication that caloric restriction imposed on pullets during the growing period had any effect on egg size during the first three months of egg production. Milby and Sherwood (1956) reported that egg weight on any calendar date was not affected by restricting the feed or nutrient intake of growing pullets.

Hollands and Gowe (1961) reported two experiments which pertained to the restriction of feed intake. In one experiment yearly egg size of pullets reared on restricted diets was smaller than that of pullets reared on full-fed diets. In the second experiment no difference in egg size occurred due to the rearing treatment. Data presented by Isaacks _et al_. (1960) indicate that the effects of restriction upon egg size may be influenced by the season of hatch.

Feed Efficiency: It was reported by Ringrose (1958) that the primary advantage of a restricted feeding program lies in the feed saved and the economy which results in the cost of growing pullets. Hollands and Gowe (1961) found no difference in feed consumption following the restriction period between limited and full-fed pullets. Berg and Bearse (1961) noted that the restriction of feed intake during the growing period did not increase feed consumption during the laying year.

The research work conducted by Honegger Farms Co., Inc. (Anonymous, 1963) demonstrated that restricted-fed pullets could be raised to 21 weeks of age on 3.38 fewer pounds of feed than were required by full-fed controls. However, the first three months these restricted-fed pullets were on full feed in the laying house, they consumed 1.3 pounds more feed per bird than did pullets raised on a full-feeding program. After the first three months in the laying house, feed consumption was approximately the same for the two groups. These research workers concluded that restricting feed during the growing period was economically sound for a started pullet grower, but economically unsound for a started pullet buyer.

Young et al. (1961) reported that restricted-fed birds over-consumed the laying ration during the first few weeks after they were transferred from the rearing program, consequently almost canceling any saving in feed which may have occurred during the period of restriction. Milby and Sherwood (1956) concluded that restricting the feed intake of growing pullets did not result in any saving in feed cost up to the time the first egg was laid, because of the fact that the limited-fed birds required a longer feeding period to reach sexual maturity. Fuller and Dunahoo (1962) found no statistical difference in the amount of feed consumed by pullets to reach sexual maturity whether they were reared on a restricted or ad libitum feeding program. McSpadden (1956) reported that the total feed consumption of restricted and full-fed pullets was not greatly affected when the feed consumed during the growing period plus one year of egg production was considered.

MacIntyre and Gardner (1964) found that feed efficiency over both the growing and laying periods was better for pullets restricted in feed intake up to the 25th week of age. However, the difference was not significant. In contrast, Harms (1962) noted that pullets grown on a restricted feeding program required a larger amount of feed to produce a dozen eggs than pullets reared on a full-feeding program. The reasons for this are the low rate of egg production during the first two months in the laying house and the unusually high consumption of feed by the restricted-fed pullets. It appeared that the pullets reared on a restricted feeding regimen formed the habit of over-consuming feed when first placed on *ad libitum* feeding. This may have been an attempt to gain their normal body weight, but they failed to readjust after reaching the body weight of the controls.

Economic Returns: Whether there are any economic advantages to be gained from raising pullets on a restricted feeding program appears to be uncertain. Gowe *et al.* (1960) reported that the economic returns of a limited feeding program were substantially larger than those of full-fed control birds. This is not in agreement with research workers at Honegger Farms Co., Inc. (Anonymous, 1963), however, who found that pullets reared on *ad libitum* feeding of a high efficiency ration returned $1.50 income on a per pullet housed basis compared to $1.46 for pullets reared on a restricted feeding program.

Conclusions: Bruckner and Hill (1959) made the following statement: "The effects of rearing treatment on adult productivity are part of a complex set of interrelationships involving strain characteristics, environment, disease and nutrition. It would seem unlikely that one rearing system would be best for all or even most conditions. In fact, the adaptability of the chicken to the wide range of rearing treatments we have studied seems more remarkable than the differences we have observed between them."

Creek (1958) concluded that in the rearing of Leghorn-type pullets, restriction of feed intake has little or no value. Young et al. (1961) concluded that either limited feeding of a complete grower ration or the restricting of energy alone to developing pullets might be more detrimental than if a standard feeding practice were used. Research workers at Honegger Farms Co., Inc. (Anonymous, 1963) concluded that they could not recommend restricted feeding during the growing period when birds are limited to 70 percent of the amount of a complete high-efficiency ration which they normally would eat.

In contrast to these conclusions, Clark et al. (1962) reported that it might be advisable to use a restricted feeding program for growing replacement pullets if the factor of prime importance is to obtain a maximum number of large eggs. Ringrose (1958) concluded that a restricted feeding program for growing pullets could be recommended to those who wish to use this rearing method. This recommendation was made on the basis of economy in the cost of growing pullets.

Present Outlook: Any study of the nutrient requirements of poultry or livestock should involve total food intake and the factors which control food intake. The individual physiological mechanisms through which food intake is regulated and controlled have been delineated by research workers in the field of physiology. A comprehensive review paper in which this research is summarized was written by Anand (1961).

The basic findings from research of this type have not been applied, either singly or in combination, to any great extent in studying the nutrient requirements of growing pullets. Such an application has been made by Gleaves *et al*. (1963a) and Gleaves (1965) in studies with laying hens using dietary protein, dietary energy, dietary volume and dietary weight as the experimental variables.

It is logical to conclude that a similar approach to the problem of determining the nutritive requirements of growing pullets could be made using the same techniques. It is the opinion of the author that this is the most promising research alternative now available, in view of the current situation as it is summarized in this literature review. For this reason, the basic experimental design and the experimental techniques applied so effectively by Gleaves *et al*. (1963a) have been utilized in the experiment reported in this thesis.

EXPERIMENTAL METHODS AND PROCEDURES

Housing and Equipment

The study which is reported in this thesis was conducted in the Battery Laboratory located on the Oklahoma State University Poultry Farm. The Battery Laboratory is a wood frame, one-story building that contains a starting room, a service room and a finishing room. Each room is equipped with aluminum awning-type, glass windows and roof-top ventilators fitted with motor-driven fans. The dimensions of the starting room are 24 by 24 feet (576 square feet of floor space). It is equipped with thermostatically controlled natural gas heaters and eight battery brooders. Each battery brooder has five decks, each of which contains a heating unit, feed and water troughs and a wire mesh bottom.

The dimensions of the finishing room are 24 by 58 feet (1392 square feet of floor space). The finishing room is equipped with manually operated natural gas heaters and 240 individual, suspended, wire laying cages. Each cage is 10 inches wide and 18 inches from front to back and furnished with an automatic drinking cup, a feeder and a feed storage container. During the daylight hours, the house is lighted naturally. The house is equipped with incandescent lights which can be used when additional light is needed. These incandescent lights in the finishing room are controlled by an automatic time clock.

Experimental Design

The experiment herein reported consisted of three phases, each having a completely randomized design. The first phase of the experiment was initiated when the chicks were day-old and lasted until the chicks were eight weeks of age. The treatments imposed during this period of time consisted of two levels of dietary protein (see Table I). Dietary energy, dietary volume and dietary weight levels were the same in each of the two treatments in phase 1, although, as will be noted, changes in dietary protein, dietary energy, dietary volume and dietary weight were made at the end of the first two periods. Each period had a duration of 14 days. The dietary nutrient levels were changed every 28 days in order to meet the changing requirements of the growing pullets. The dietary volume maintained during periods 1 and 2 was increased during periods 3 and 4 in order to condition the pullets to the extreme dietary volume levels which were to be imposed by certain treatments during phase 2 of the experiment.

During the first six weeks of the experiment, each treatment consisted of 15 battery decks in the electric battery brooders. There were 10 chicks in each deck. Thus, each treatment level was applied to 150 chicks.

At the beginning of the seventh week (period 4) 117 pullets from each treatment were randomly selected and moved into individual wire laying cages. Thus, during period 4 each treatment consisted of 117 pullets, each pullet being an experimental unit.

The second phase of the experiment was imposed during the growing period between the ninth week (period 5) and the 20th week

TABLE I

SELECTED DAILY DIETARY LEVELS USED IN THE FORMULATION OF ALL RATIONS

Nutrient	Level							
		Period	1,2	3,4	5,6	7,8	9,10	11-20
		Week	1-4	5-8	9-12	13-16	17-20	21-40
		Phase	1	1	2	2	2	3
<u>Dietary protein</u>								
grams	1		4.03	9.30	10.36	10.62	10.93	17.50
	2		4.98	11.62	13.32	13.89	14.58	
<u>Dietary energy</u>								
Calories of	1				130.40	143.96	160.53	320.00
metabolizable	2		52.20	127.97	163.00	179.96	200.66	
energy	3				195.60	215.96	240.79	
<u>Dietary volume</u>								
milliliters	1		33.18		103.60	114.38	127.54	200.00
	2			122.01	155.40	171.57	191.31	
	3				207.20	228.76	255.08	
<u>Dietary weight</u>								
grams			23.70	58.10	87.70	100.00	110.00	119.47
Ration numbers containing these levels			1,2	3,4	5-22	23-40	40-58	59

(period 10). The pullets from each treatment level of dietary protein were randomly distributed among 9 treatments which involved three levels of dietary energy and three levels of dietary volume (see Tables I and II). Each series of experimental rations within each of the 18 treatments was fed to 13 pullets in individual cages. This sub-division created a 3x3x2 factorial arrangement of treatments. After each pullet had been randomly assigned to a treatment, all pullets were distributed randomly among the cages in the house.

The third phase of the experiment started with the twenty-first week (period 11) and extended until the pullets had exceeded peak egg production at 40 weeks of age (period 20). During this time the pullets were all fed the same laying ration. Effects from the growing period treatments were measured during this egg production period.

Management

The experiment was initiated on September 12, 1963 with 300 day-old, Heisdorf & Nelson strain egg-type pullets which had been decombed. The day-old chicks were individually wing-banded and vaccinated with Newcastle-infectious bronchitis vaccine. They were then randomly placed in 30 battery brooder pens in the starting room. All pullets were given feed and water ad libitum during the entire experiment. At the time the pullets were seven weeks of age, they were moved into the individual laying cages in the finishing room where they stayed throughout the remainder of the experiment.

The pullets were reared on continuous 24 hours of light per day for the first six weeks of their life. For the remainder of the

TABLE II

FACTORIAL ARRANGEMENT OF TREATMENTS BY RATIONS AND BY PERIODS

Volume level	Energy level 1				Energy level 2				Energy level 3			
	Protein level 1		Protein level 2		Protein level 1		Protein level 2		Protein level 1		Protein level 2	
	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed
1	2	1,2	1	1,2	2	1,2	1	1,2	2	1,2	1	1,2
	4	3,4	3	3,4	4	3,4	3	3,4	4	3,4	3	3,4
	22	5,6	13	5,6	19	5,6	10	5,6	16	5,6	7	5,6
	40	7,8	31	7,8	37	7,8	28	7,8	34	7,8	25	7,8
	58	9,10	49	9,10	55	9,10	46	9,10	52	9,10	43	9,10
	Treatment 18		Treatment 9		Treatment 15		Treatment 6		Treatment 12		Treatment 3	
	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed
2	2	1,2	1	1,2	2	1,2	1	1,2	2	1,2	1	1,2
	4	3,4	3	3,4	4	3,4	3	3,4	4	3,4	3	3,4
	21	5,6	12	5,6	18	5,6	9	5,6	15	5,6	6	5,6
	39	7,8	30	7,8	36	7,8	27	7,8	33	7,8	24	7,8
	57	9,10	48	9,10	54	9,10	45	9,10	51	9,10	42	9,10
	Treatment 17		Treatment 8		Treatment 14		Treatment 5		Treatment 11		Treatment 2	
	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed	Ration number	Period fed
3	2	1,2	1	1,2	2	1,2	1	1,2	2	1,2	1	1,2
	4	3,4	3	3,4	4	3,4	3	3,4	4	3,4	3	3,4
	20	5,6	11	5,6	17	5,6	8	5,6	14	5,6	5	5,6
	38	7,8	29	7,8	35	7,8	26	7,8	32	7,8	23	7,8
	56	9,10	47	9,10	53	9,10	44	9,10	50	9,10	41	9,10
	Treatment 16		Treatment 7		Treatment 13		Treatment 4		Treatment 10		Treatment 1	

experiment the pullets were given 14 hours of light and 10 hours of continuous darkness during each 24-hour period.

At 12 weeks of age, all pullets were vaccinated against chicken pox by the wing-web method. At 18 weeks of age, all pullets were vaccinated with a combination of Newcastle and infectious-bronchitis vaccine.

Rations

The rations used in this study were formulated by the daily nutrient intake method of Gleaves et al. (1963b). In order to have a factorial arrangement of treatments, various levels of dietary protein, dietary energy and dietary volume for each ration were selected, along with dietary weight. These selected daily dietary levels were used in place of the daily nutrient intake standard for pullets, as recommended by Gleaves et al. (1963b). The two dietary levels of protein ranged from the upper to the lower practical extremities reported by poultry research workers. The dietary levels of energy were selected in a similar way except that an intermediate level, equally spaced between the two extreme levels, was selected. Three equally spaced levels of dietary volume were also selected, based upon data accumulated in work with laying hens. The dietary weight levels used were selected from actual feed intake figures reported by Gleaves et al. (1963b) and Taylor et al. (1960). These selected dietary levels are presented in Table I.

Dietary weight may be defined as a daily feed consumption figure in grams selected as being within the range of possible feed consumption at a particular time during the growing or egg production period. Dietary protein is the number of grams of protein in the dietary weight selected. Dietary energy is the number of Calories of metabolizable energy in the dietary weight selected. Dietary volume is the number of milliliters occupied by the dietary weight selected.

The total dietary volume of each experimental ration was calculated by summing the number of milliliters of volume contributed by each ingredient. The dietary volume figures of the feed ingredients used in this experiment were taken from Gleaves et al. (1963b) and Tarpey et al. (1965) and are presented in Table III.

Polyethylene fluff was used to vary the dietary volume of the rations fed during the second phase of the experiment. Washed blow sand was used to hold dietary weight in each concurrently fed ration constant during phases 1 and 2 of the experiment.

The protein basal and the two energy basals used in the formulations of the experimental rations are shown in Tables IV, VI and VII. The amino acid profile of the protein basal is shown in Table V.

The compositions of the rations as formulated are shown in Table VIII. Dietary nutrient levels in the rations were changed every four weeks during the starting and growing period (20 weeks) in order to meet the changing requirements of the growing pullets.

In Table IX, the composition of vitamin-mineral concentrate VMC-60 is given. The composition of the vitamin concentrate VC-60A which was added to rations 1 and 2 is listed in Table X. Dicalcium phosphate and calcium carbonate were added to all experimental ra-

TABLE III

VOLUME OF FEED INGREDIENTS[1]

Feed ingredient	Milliliters occupied per gram of ingredient
Corn, ground	1.508
Milo, ground	1.462
Oat mill feed	2.331
Dehydrated alfalfa meal (17% protein)	1.872
Fish meal (70% protein)	1.710
Soybean oil meal (50% protein)	1.439
Blood meal (84% protein)	1.954
Gelatin (95% protein)	1.440
Dried whey (12% protein)	1.391
Dried condensed fermented corn extractives (28% protein)	1.800
dl-Methionine	2.331
Tallow	1.087
Starch	1.340
Polyethylene fluff	4.510
Sand	0.763
Dicalcium phosphate	0.536
Calcium carbonate	0.803
Salt	0.763
VMC-60	1.432
VC-60A	1.432

[1]These volume figures were calculated on a dry basis.

tions to meet the calcium and phosphorus standards published by Gleaves *et al.* (1963b).

Salt and VMC-60 were added to rations 5 through 58 (phase 2) on a graded level in proportion to the energy level of the individual ration. Recommended levels of salt and VMC-60 were added to all rations containing energy level 2. The recommended amounts of these two ingredients were increased 20 percent in all rations containing energy level 3, while the recommended level of these two ingredients was decreased 20 percent in all rations containing

TABLE IV

COMPOSITION OF PROTEIN BASAL[1]

Ingredient	Grams
Yellow corn	5.00
Milo	5.00
Oat mill feed	4.77
Dehydrated alfalfa meal (17% protein)	2.00
Fish meal (70% protein)	7.50
Soybean oil meal (50% protein)	15.00
Blood meal (84% protein)	4.00
Gelatin (95% protein)	2.00
Dried whey (12% protein)	2.00
Dried condensed fermented corn extractives (28% protein)	2.50
dl-Methionine	0.23
Total	50.00

[1]Used in all rations fed during this experiment.

TABLE V

AMINO ACID PROFILE OF THE PROTEIN BASAL

Amino acid	Gram of amino acid per gram of protein	Amino acid	Gram of amino acid per gram of protein
Arginine	.064	Threonine	.039
Histidine	.029	Leucine	.090
Lysine	.067	Isoleucine	.040
Tyrosine	.028	Valine	.065
Tryptophan	.010	Glutamic Acid	.142
Phenylalanine	.046	Aspartic Acid	.096
Cystine	.013	Glycine	.065
Methionine	.028	Alanine	.063
Serine	.051	Proline	.064
		Total	1.000

TABLE VI

COMPOSITION OF ENERGY BASAL NUMBER 1[1]

Ingredient	Grams
Tallow	5.0
Starch	5.0
Total	10.0

[1]This basal was used in rations 1-58 inclusive.

TABLE VII

COMPOSITION OF ENERGY BASAL NUMBER 2[1]

Ingredient	Grams
Corn	19.0
Milo	29.0
Oat mill feed	34.0
Tallow	5.0
Total	87.0

[1]This basal was used in ration 59 only.

energy level 1. This was done because research at the Oklahoma Station indicated that the vitamin and mineral content of a ration has little or no effect on feed consumption while energy has a pronounced effect. Adding salt and VMC-60 at these graded levels makes possible a more uniform intake of salt, vitamins and trace minerals.

The factorial arrangement of treatments with individual ration numbers making up each treatment are shown in Table II. These rations were formulated to contain the dietary levels which are shown in Table I.

TABLE VIII

COMPOSITION OF RATIONS (IN GRAMS)

Ration number	Protein basal	Energy basal	Polyethylene fluff	Sand	Dicalcium phosphate	Calcium carbonate	Salt	VMC-60	VC-60A	Total	Period fed
1	12.02	3.67	0.95	5.01	1.09	0.66	0.12	0.12	0.06	23.7	1,2
2	9.73	4.80	1.36	5.70	1.15	0.66	0.12	0.12	0.06	23.7	1,2
3	28.05	9.70	13.11	1.79	3.07	1.80	0.29	0.29	-	58.1	3,4
4	22.45	12.45	14.11	3.50	3.21	1.80	0.29	0.29	-	58.1	3,4
5	32.16	20.08	27.52	0.79	3.86	2.23	0.53	0.53	-	87.7	5,6
6	32.16	20.08	14.11	14.20	3.86	2.23	0.53	0.53	-	87.7	5,6
7	32.16	20.08	0.70	27.61	3.86	2.23	0.53	0.53	-	87.7	5,6
8	32.16	14.11	28.23	6.23	3.86	2.23	0.44	0.44	-	87.7	5,6
9	32.16	14.11	14.82	19.64	3.86	2.23	0.44	0.44	-	87.7	5,6
10	32.16	14.11	1.41	33.05	3.86	2.23	0.44	0.44	-	87.7	5,6
11	32.16	8.13	28.95	11.67	3.86	2.23	0.35	0.35	-	87.7	5,6
12	32.16	8.13	15.54	25.08	3.86	2.23	0.35	0.35	-	87.7	5,6
13	32.16	8.13	2.13	38.49	3.86	2.23	0.35	0.35	-	87.7	5,6
14	25.01	23.59	28.79	2.99	4.03	2.23	0.53	0.53	-	87.7	5,6
15	25.01	23.59	15.38	16.40	4.03	2.23	0.53	0.53	-	87.7	5,6
16	25.01	23.59	1.97	29.81	4.03	2.23	0.53	0.53	-	87.7	5,6
17	25.01	17.61	29.51	8.43	4.03	2.23	0.44	0.44	-	87.7	5,6

TABLE VIII (continued)

Ration number	Protein basal	Energy basal	Polyethylene fluff	Sand	Dicalcium phosphate	Calcium carbonate	Salt	VMC-60	VC-60A	Total	Period fed
18	25.01	17.61	16.10	21.84	4.03	2.23	0.44	0.44	-	87.7	5,6
19	25.01	17.61	1.79	36.15	4.03	2.23	0.44	0.44	-	87.7	5,6
20	25.01	11.64	30.23	13.86	4.03	2.23	0.35	0.35	-	87.7	5,6
21	25.01	11.64	16.82	27.27	4.03	2.23	0.35	0.35	-	87.7	5,6
22	25.01	11.64	3.41	40.68	4.03	2.23	0.35	0.35	-	87.7	5,6
23	33.53	23.14	30.15	5.01	4.44	2.53	0.60	0.60	-	100.0	7,8
24	33.53	23.14	15.34	19.82	4.44	2.53	0.60	0.60	-	100.0	7,8
25	33.53	23.14	0.49	34.67	4.44	2.53	0.60	0.60	-	100.0	7,8
26	33.53	16.54	30.94	11.02	4.44	2.53	0.50	0.50	-	100.0	7,8
27	33.53	16.54	16.14	25.82	4.44	2.53	0.50	0.50	-	100.0	7,8
28	33.53	16.54	1.33	40.63	4.44	2.53	0.50	0.50	-	100.0	7,8
29	33.53	9.94	31.74	17.02	4.44	2.53	0.40	0.40	-	100.0	7,8
30	33.53	9.94	16.93	31.83	4.44	2.53	0.40	0.40	-	100.0	7,8
31	33.53	9.94	2.13	46.63	4.44	2.53	0.40	0.40	-	100.0	7,8
32	25.64	27.01	31.56	7.43	4.63	2.53	0.60	0.60	-	100.0	7,8
33	25.64	27.01	16.75	22.24	4.63	2.53	0.60	0.60	-	100.0	7,8
34	25.64	27.01	1.95	37.04	4.63	2.53	0.60	0.60	-	100.0	7,8
35	25.64	20.41	32.35	13.44	4.63	2.53	0.50	0.50	-	100.0	7,8

TABLE VIII (continued)

Ration number	Protein basal	Energy basal	Polyethylene fluff	Sand	Dicalcium phosphate	Calcium carbonate	Salt	VMC-60	VC-60A	Total	Period fed
36	25.64	20.41	17.55	28.24	4.63	2.53	0.50	0.50	-	100.0	7,8
37	25.64	20.41	2.74	43.05	4.63	2.53	0.50	0.50	-	100.0	7,8
38	25.64	13.81	33.14	19.45	4.63	2.53	0.40	0.40	-	100.0	7,8
39	25.64	13.81	18.34	34.25	4.63	2.53	0.40	0.40	-	100.0	7,8
40	25.64	13.81	3.53	49.06	4.63	2.53	0.40	0.40	-	100.0	7,8
41	35.20	26.87	34.28	4.62	4.93	2.78	0.66	0.66	-	110.0	9,10
42	35.20	26.87	17.78	21.12	4.93	2.78	0.66	0.66	-	110.0	9,10
43	35.20	26.87	1.27	37.63	4.93	2.78	0.66	0.66	-	110.0	9,10
44	35.20	19.52	35.17	11.30	4.93	2.78	0.55	0.55	-	110.0	9,10
45	35.20	19.52	18.66	27.81	4.93	2.78	0.55	0.55	-	110.0	9,10
46	35.20	19.52	2.15	44.32	4.93	2.78	0.55	0.55	-	110.0	9,10
47	35.20	12.16	36.05	18.00	4.93	2.78	0.44	0.44	-	110.0	9,10
48	35.20	12.16	19.55	34.50	4.93	2.78	0.44	0.44	-	110.0	9,10
49	35.20	12.16	3.04	51.01	4.93	2.78	0.44	0.44	-	110.0	9,10
50	26.39	31.20	35.86	7.30	5.14	2.79	0.66	0.66	-	110.0	9,10
51	26.39	31.20	19.35	23.81	5.14	2.79	0.66	0.66	-	110.0	9,10
52	26.39	31.20	2.84	40.32	5.14	2.79	0.66	0.66	-	110.0	9,10
53	26.39	23.84	36.74	14.00	5.14	2.79	0.55	0.55	-	110.0	9,10

TABLE VIII (continued)

Ration number	Protein basal	Energy basal	Polyethylene fluff	Sand	Dicalcium phosphate	Calcium carbonate	Salt	VMC-60	VC-60A	Total	Period fed
54	26.39	23.84	20.23	30.51	5.14	2.79	0.55	0.55	-	110.0	9,10
55	26.39	23.84	3.73	47.01	5.14	2.79	0.55	0.55	-	110.0	9,10
56	26.39	16.48	37.63	20.69	5.14	2.79	0.44	0.44	-	110.0	9,10
57	26.39	16.48	21.12	37.20	5.14	2.79	0.44	0.44	-	110.0	9,10
58	26.39	16.48	4.61	53.71	5.14	2.79	0.44	0.44	-	110.0	9,10
59	27.83	82.34	--	--	4.39	3.72	0.60	0.60	-	119.5	11-20

TABLE IX

VITAMIN-MINERAL CONCENTRATE VMC-60

Vitamins and minerals	Units	Units contained in 10 lbs. of concentrate	Adds per lb. of finished ration, when added at the 0.5 percent level
Vitamin A	U.S.P.	16,000,000	8,000
Vitamin D_3	I.C.U.	2,400,000	1,200
Vitamin E	I.U.	12,000	6
Vitamin K	Mg.	6,000	3
Vitamin B_{12}	Mg.	16	0.008
Riboflavin	Mg.	8,000	4
Niacin	Mg.	64,000	32
Pantothenic Acid	Mg.	16,000	8
Choline Chloride	Mg.	1,000,000	500
Manganese	Mg.	55,400	27.7
Iodine	Mg.	1,720	0.86
Cobalt	Mg.	1,180	0.59
Iron	Mg.	43,600	21.8
Copper	Mg.	3,300	1.65
Zinc	Mg.	45,400	22.7

TABLE X

VITAMIN CONCENTRATE VC-60A

Vitamins	Units	Units contained in 5 lb. of concentrate	Adds per lb. of finished ration when added at the 0.25 percent level
Pyridoxine	Mg.	16,000	8
Biotin	Mg.	600	0.3
Thiamin	Mg.	24,000	12
Folic acid	Mg.	4,000	2
Inositol	Mg.	100,000	50
Para amino benzoic acid	Mg.	8,000	4
Ascorbic acid	Mg.	20,000	10

Data and Statistical Analysis

Individual feed consumption and body weight data were recorded at two-week intervals during the entire experiment. Egg production, egg weight, and mortality were recorded daily. From these data, the following values were computed for each period: daily intake of protein, energy, feed volume, and feed weight; body weight gain; egg numbers; and egg weights.

Analyses, as they were applicable, were made for each period and overall for each phase on the following responses: feed weight consumption, feed volume consumption, energy consumption, protein consumption, body weight gain, egg production and egg size. Since the pullets were moved at the beginning of period 4, it was considered to be an adjustment period, and these data were not included in the overall analyses of phase 1. Because egg production started during period 10 these data were not included in the overall analyses of phase 2.

The analyses for the first to the third periods were based on weighted pen averages. The analyses for the other periods were based on individual bird data. Missing data values for periods four through twenty were supplied by using treatment averages.

All analyses of variance were calculated using the method outlined by Snedecor (1956). Because of the large amount of data collected from this experiment, electronic computing equipment was used.

RESULTS AND DISCUSSION

Phase 1

A three percent death loss occurred during phase 1 of the experiment. The breakdown of this death loss revealed that a five percent mortality occurred on protein level 1 compared to one percent on protein level 2. To determine if there were real differences in mortality due to treatment, an analysis of variance was performed on the mortality data recorded for periods 1 through 3. No statistically significant difference in mortality was found due to treatment.

Mortality was low during period 4 with the loss of only two pullets, both on protein level 1. Therefore, to make maximum use of all data collected, treatment averages were supplied for dead birds in all analyses and means computed for period 4.

Although the mortality differences among treatments were not statistically significant, the trend should be noted that pullets reared on the low-protein level had a higher death rate than pullets reared on the high-protein level. Further evidence supporting this trend may be seen in other phases of the experiment.

Feed Weight Consumed

The means and analyses of variance for each period and overall for periods 1 through 3, for average feed weight consumed per

TABLE XI

MEANS AND ANALYSES OF VARIANCE OF FEED WEIGHT CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 1

MEANS

Protein level	Periods 1	2	3	Overall 1-3	4
1	15.6	31.9	46.2	31.5	59.9
2	15.7	33.6	48.2	32.8	62.5

ANALYSES OF VARIANCE

Source of variation	df	M.S.	M.S.	M.S.	M.S.	df	M.S.
Total	29					233	
Protein	1	0.03	20.20*	30.41*	13.87**	1	401.46
Error	28	0.49	3.00	5.31	1.41	232	209.25

[1]All means are expressed in average grams per bird per day.
[2]Overall based upon combined data for periods 1 through 3.
*Significant at the five percent level of probability.
**Significant at the one percent level of probability.

bird per day are shown in Table XI. Inspection of the data in this table shows that during period 1 there was no statistically significant difference in feed consumed. However, during periods 2 and 3 the analyses of variance performed on feed weight consumed show a significant difference in feed consumption at the five percent level of probability. Upon examination of the means for periods 2 and 3, it may be seen that pullets reared on protein level 2 consumed 1.7 and 2.0 more grams of feed, respectively, than pullets reared on protein level 1. The overall analysis of variance for periods 1 through 3 shows a significant difference in feed consumption at the one percent level of probability. These significant differences in feed consumption for periods 2 and 3, and overall for periods 1 through 3, may be explained by the facts that pullets reared on protein level 2 gained more weight and developed larger bodies. This would in turn cause them to consume slightly larger amounts of feed.

TABLE XII

MEANS AND ANALYSES OF VARIANCE OF FEED VOLUME CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 1

MEANS						
Protein level	Periods 1	2	3	Overall 1-3		4
1	21.8	44.7	97.1	55.0		125.8
2	21.9	47.0	101.3	57.5		131.3

ANALYSES OF VARIANCE							
Source of variation	df	M.S.	M.S.	M.S.	M.S.	df	M.S.
Total	29					233	
Protein	1	0.08	38.76*	135.26*	46.38**	1	1,772.93
Error	28	0.99	5.84	23.58	4.56	232	923.07

[1]All means are expressed in average milliliters per bird per day.

[2]Overall based upon combined data for periods 1 through 3.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

The analysis of variance for period 4 feed consumption shows no significant difference due to treatment; although, the means for period 4 follow the same trend as the three previous periods. As has been mentioned in the experimental methods and procedures, during period 4 the pullets in both treatments were adjusting to the added stress placed upon them as a result of having been moved to individual laying cages. This stress might account in part for the lack of significance during this period. The stress effect during this period is confounded with the treatment effect.

TABLE XIII

MEANS AND ANALYSES OF VARIANCE OF ENERGY CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 1

MEANS

Protein level	Periods 1	2	3	Overall 1-3	4
1	34.3	70.3	101.8	69.5	132.0
2	34.5	73.7	106.3	72.3	137.7

ANALYSES OF VARIANCE

Source of variation	df	M.S.	M.S.	M.S.	M.S.	df	M.S.
Total	29					233	
Protein	1	0.13	86.71*	149.64*	61.63**	1	1,929.85
Error	28	2.25	14.44	25.69	6.47	232	1,017.06

[1]All means are expressed in average Calories per bird per day.
[2]Overall based upon combined data for periods 1 through 3.
*Significant at the five percent level of probability.
**Significant at the one percent level of probability.

Feed Volume and Energy Consumed

The means and analyses of variance for each period and overall for periods 1 through 3, for feed volume and energy consumed are shown in Table XII and Table XIII, respectively. They follow the pattern of feed weight consumed as shown in Table XI. This would be expected because the dietary level of volume and energy were held constant in both treatments during phase 1 of this experiment (see Table I).

TABLE XIV

MEANS AND ANALYSES OF VARIANCE OF PROTEIN CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 1

MEANS

Protein level	Periods 1	2	3	Overall 1-3	4
1	2.7	5.4	7.4	5.2	9.6
2	3.3	7.1	9.6	6.7	12.5

ANALYSES OF VARIANCE

Source of variation	df	M.S.	M.S.	M.S.	M.S.	df	M.S.
Total	29					233	
Protein	1	3.06**	19.76**	37.89**	17.66**	1	497.04**
Error	28	0.02	0.12	0.20	0.05	232	8.05

[1]All means are expressed in average grams per bird per day.
[2]Overall based on combined data for periods 1 through 3.
**Significant at the one percent level of probability.

Protein Consumed

The means and analyses of variance, for each period and overall for periods 1 through 3, for protein consumed are shown in Table XIV. These means show that pullets reared on dietary protein level 2 consumed more protein during every period of phase 1 than did pullets reared on dietary protein level 1. The analyses of variance performed on the original data from which these means were computed show a significant difference in protein consumption at the one percent level of probability for all periods during phase 1. Differences of this magnitude are expected; first, because of the two levels of protein imposed as treatments during this phase and; second, because the pullets reared on dietary protein level 2 had larger body sizes than those pullets reared on dietary protein level 1.

Body Weight Gain

The means and analyses of variance for body weight gain are shown for each period and overall for periods 1 through 3 in Table XV. The analyses of variance performed for periods 1 and 2 and overall for periods 1 through 3 show a difference in body weight gain significant at the one percent level of probability. The means for periods 1 and 2 and overall for periods 1 through 3 show that pullets reared on protein level 2 gained 8.0, 19.4, and 40.8 more grams, respectively, than did pullets reared on protein level 1. This significant difference might be expected as a result of the increased protein intake previously reported for birds reared on protein level 2. In contrast, there was no significant difference in body weight gain during periods 3 or 4. However, during period 3 the difference due to treatment approached significance at the five percent level. This can be seen in Table XV by comparing the protein mean square to the error term.

TABLE XV

MEANS AND ANALYSES OF VARIANCE OF BODY WEIGHT GAIN[1] FOR EACH PERIOD AND OVERALL[2], PHASE 1

MEANS						
Protein level	Periods					
	1	2	3	Overall 1-3		4
1	94.6	154.0	165.2	413.8		196.4
2	102.6	173.4	178.2	454.2		191.4

ANALYSES OF VARIANCE

Source of variation	df	M.S.	M.S.	M.S.	M.S.	df	M.S.
Total	29					233	
Protein	1	480.00**	2,822.70**	1,267.50	12,689.63**	1	1,472.52
Error	28	24.33	41.63	305.74	464.99	232	1,357.80

[1]All means are expressed in grams.

[2]Overall based upon combined data for periods 1 through 3.

**Significant at the one percent level of probability.

The trend in the body weight gain established during periods 1 and 2 continued during period 3. However, during period 4, this trend was changed as the pullets fed dietary protein level 1 out-gained pullets fed dietary protein level 2 by five grams. A reason for this change in body weight gain trend during period 4 could have been the added stress placed upon the pullets in both treatments when they were moved at the beginning of this period.

A further study of the data concerning this change in trend for body weight gain indicates that at the selected dietary levels used in this experiment (see Table I), protein needs are more critical during the first four weeks of the pullet's life than during the second four weeks. Other apparent critical periods for protein intake will be discussed in phases 2 and 3.

It should also be pointed out that the change in trend of body weight gain during period 4 may have resulted from the lack of complete randomized selection which occurred when the pullets were moved and regrouped at the seventh week of age. It was assumed by the author that if light-weight pullets, whose capabilities to produce eggs were questionable, were selected to continue the experiment, the collection of future data would be jeopardized. Consequently, the light-weight and unthrifty pullets were culled. More light-weight pullets were found on protein level 1 than on protein level 2. As a result, 21 pullets were culled from the original 117 randomly selected pullets on protein level 1 and replaced with larger, extra pullets from the same treatment. In contrast, only eight light-weight pullets were culled from the original 117 randomly selected pullets on protein level 2.

It is possible that this method of selection could have eliminated the treatment differences. As a check to see if this had occurred, an analysis of variance was performed for body weight gain during period 4. Data from the 96 pullets which had been originally selected at random from dietary protein level 1 and the first 96 pullets which had been originally selected at random from dietary protein level 2 were used in this analysis.

The results of this analysis of variance showed the same results as reported in the period 4 body weight gain analysis. There was no significant difference due to dietary protein level and the means were similar to those reported in Table XV for period 4. This infers that the treatment differences as reflected by body weight probably were not selected out of the experiment by this lack of complete randomization, although it is recognized that bias may have entered the experiment at this point.

Phase 2

Only one bird died during the entire 12-week growing period covered by phase 2. This bird was reared on dietary protein level 1. An analysis of variance was computed on the mortality data recorded during phases 2 and 3. This analysis of variance showed that death loss could not be attributed to any particular treatment. Therefore, in order to make full use of all data collected, treatment averages were supplied for all dead birds during phases 2 and 3 of the experiment.

As has been mentioned earlier in experimental methods and procedures, period 10 was not included with periods 5 through 9 in the overall analysis of phase 2. It was originally planned to include period 10 in the summary analyses, but because egg production started during this period, it was not included. It is well recognized from other research work that egg production would have a pronounced effect on such responses as feed consumption and body weight gain.

Analyses were performed for each period during phase 2 in order to observe periodic trends or changes. These are reported in the following discussion.

Feed Weight Consumed

The mean squares for feed weight consumed, for each period and overall for periods 5 through 9, are shown in Table XVI. Examination of this table reveals that no significant interactions occurred during phase 2.

There was no significant difference in overall feed consumption due to dietary protein for periods 5 through 9. However, a difference in feed consumption due to dietary protein was significant at the one percent level of probability during period 9 and significant at the five percent level of probability during periods 6 and 10.

The data in Table XVII show that during periods 5 and 6, the pullets fed dietary protein level 1 consumed more grams of feed than did those fed level 2. The trend changes during periods 7 and 8, with pullets on both levels of dietary protein consuming approximately the same amount of feed. The consumption trend as observed for periods 9 and 10, in which pullets fed dietary protein level 2 consumed more feed than those fed dietary protein level 1, was the reverse of that observed during periods 5 and 6. It will be shown later that body weight gain follows a pattern similar to feed consumption, regardless of the dietary protein level. This appears to indicate that the dietary protein level 1 is as adequate for growth as dietary protein level 2 during periods 5, 6, 7, and 8. This observation was made previously concerning the dietary protein level fed during period 4 of phase 1.

The significant difference in feed consumption due to protein

TABLE XVI

ANALYSES OF VARIANCE OF FEED WEIGHT CONSUMED FOR EACH PERIOD AND OVERALL[1], PHASE 2

Source of variation	df	Mean squares for the following periods: 5	6	7	8	9	10	overall 5-9
Total (corrected)	233							
Treatment	17							
Protein (P)	1	448	341*	11	40	2,834 **	1,770*	23
Energy (E)	(2)							
$E_{(L)}$	1	35,754**	68,665**	83,553**	94,324**	124,485**	124,339**	78,414**
$E_{(Q)}$	1	932*	1,238**	3,286**	1,509**	2,339**	3,008**	1,788**
Volume (V)	(2)							
$V_{(L)}$	1	1,342**	94	955*	1,465**	540	440	721**
$V_{(Q)}$	1	281	56	4	541	180	72	56
Interactions	(12)							
P x E	2	114	41	74	30	272	179	16
P x V	2	153	52	88	158	113	283	30
E x V	4	159	87	62	81	259	751	91
P x E x V	4	100	49	35	288	375	419	84
Error	216	184	59	166	156	323	322	88

[1]Overall based upon combined data for periods 5 through 9.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XVII

MAIN EFFECT MEANS OF FEED WEIGHT CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 2

	Periods						
	5	6	7	8	9	10	overall 5-9
Dietary protein level		*			**	*	
1	95.7	108.1	118.4	120.9	125.2	133.0	113.6
2	93.0	105.7	118.8	121.7	132.1	138.5	114.2
Dietary energy level	(L)**[3] (Q)*[4]	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**
1	110.9	129.5	144.4	147.7	159.1	166.5	138.3
2	91.5	103.6	113.3	117.7	124.2	130.7	110.0
3	80.6	87.5	98.1	98.5	102.6	110.0	93.5
Dietary volume level	(L)**		(L)*	(L)**			(L)**
1	98.0	108.0	121.2	125.5	129.9	137.8	116.5
2	92.8	106.2	118.4	119.2	129.9	134.9	113.2
3	92.2	106.4	116.2	119.3	126.2	134.4	112.1

[1]All means are expressed in average grams per bird per day.

[2]Overall based on combined data for periods 5 through 9.

[3]Linear significance

[4]Quadratic significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

during periods 9 and 10 appears to result from the preparation of pullets on dietary protein level 2 to start laying earlier and to lay more eggs early in the production year. It will be seen throughout this phase that nutrients, especially protein, are critical when rapid sexual development occurs just prior to the onset of egg production.

The linear effect of graded levels of dietary energy on feed consumption (Table XVI) shows a difference which is significant at the one percent level of probability for every period during phase 2 and overall for periods 5 through 9. The mean squares for these effects are extremely large. This linear effect is expected, for it is generally agreed among research workers that as dietary energy level increases, actual feed consumption decreases.

There was also a quadratic effect of dietary energy on feed consumption which was significant at the one percent level of probability during periods 6, 7, 8, 9, and 10, and overall, and at the five percent level during period 5. However, the energy quadratic mean squares are small compared to the linear mean squares. This would denote that the effects of energy on feed consumption are mainly linear. A possible explanation for this small quadratic effect of energy on feed consumption may be that the pullets on dietary energy level 3 consumed more feed than would be expected in an effort to take in more protein. It will be shown later that during periods 5 through 9, pullets on energy level 1 consumed 5.6 grams more protein per bird per day than pullets on dietary energy level 3 (see page 70).

The effects of dietary volume levels upon feed weight consumption showed a negative linear response which was statistically significant at the one percent level of probability during periods 5, 8 and overall, and significant at the five percent level for period 7. This pattern of significant differences (Table XVII) indicates that dietary volume was restricting feed weight consumption during the early and middle periods of phase 2, with the exception of period 6.

The lack of significant differences in feed consumption for the dietary volume levels during periods 9 and 10 infer that any restriction of feed weight consumption due to volume has disappeared. This may have resulted from the pullets outgrowing the fixed dietary volume levels used in this experiment. It could also indicate that the digestive systems of pullets on dietary volume levels 2 and 3 stretched and adjusted to the increased volume levels.

The overall mean difference of 4.4 grams in feed weight consumption between dietary volume levels 1 and 3, as shown in Table XVII, denotes that as dietary volume increases there is a corresponding decrease in feed weight consumption. This was reported by Gleaves (1965) to be true with laying hens.

Feed Volume Consumed

The mean squares for feed volume consumed for each period of phase 2 and overall for periods 5 through 9 are shown in Table XVIII. An energy x volume interaction occurred which was significant during all periods and overall. The overall means for the

TABLE XVIII

ANALYSES OF VARIANCE OF FEED VOLUME CONSUMED FOR EACH PERIOD AND OVERALL[1], PHASE 2

Source of variation	df	Mean squares for the following periods 5	6	7	8	9	10	Overall 5-9
Total (corrected)	233							
Treatment	17							
Protein (P)	1	942	910*	123	324	7,664**	8,111**	129
Energy (E)	(2)							
E_L	1	111,866**	215,114**	247,856**	277,403**	377,827**	371,954**	237,635**
E_Q	1	1,941	3,114**	8,689**	3,996**	4,797*	5,436*	4,279**
Volume (V)	(2)							
V_L	1	405,844**	599,229**	631,907**	654,242**	785,090**	906,137**	608,761**
V_Q	1	297	100	52	746	943	105	15
Interactions	(12)							
P x E	2	291	62	140	2	523	1,136	21
P x V	2	434	97	378	403	241	2,499	99
E x V	4	2,506*	4,303**	5,256**	5,634**	7,498**	8,582**	4,751**
P x E x V	4	262	166	94	704	809	1,094	195
Error	216	729	200	550	517	964	1,096	301

[1]Overall based on combined data for periods 5 through 9.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

energy; volume levels are shown in Table XIX. These means are shown graphically in Figure 1. Examination of these interaction means indicates that as the dietary energy level rises, volume consumption is depressed. In contrast, as feed volume is increased, feed volume consumption is increased. Thus, it is apparent that with dietary volume levels and dietary energy levels exerting pressures in opposite directions, an interaction will occur.

TABLE XIX

OVERALL[1] MEANS FOR THE EFFECT OF ENERGY AND VOLUME UPON FEED VOLUME CONSUMED[2]

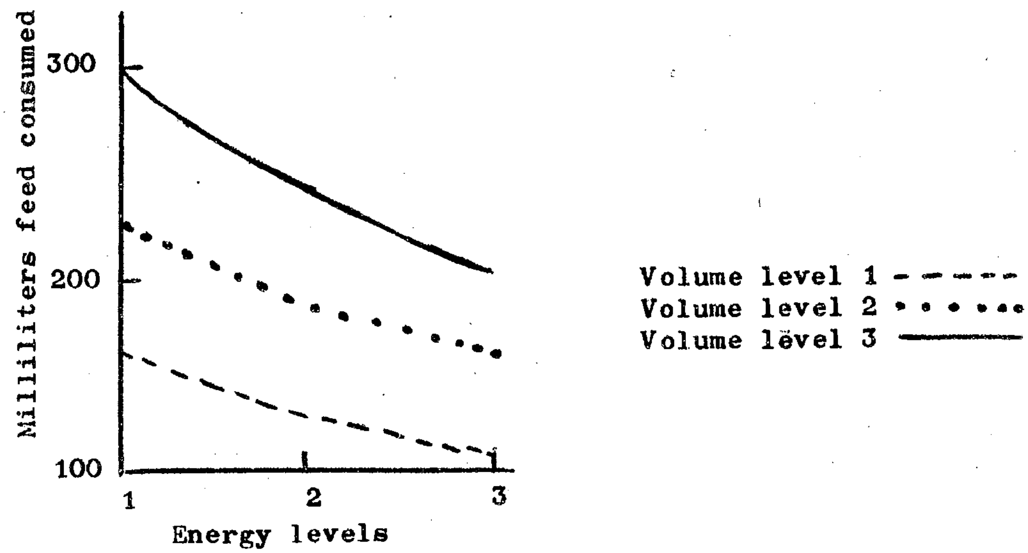
Dietary volume level	Dietary energy level[3] 1	2	3
1	165.15	128.39	112.12
2	237.70	190.66	163.17
3	315.86	255.36	209.24

[1]Overall based upon periods 5 through 9 combined.

[2]All means are expressed as average milliliters per bird per day.

[3]See Table I for the dietary equivalents of levels 1, 2, and 3 for volume and energy.

The energy x volume interaction limits the confidence that can be placed on the energy and volume main effects for feed volume consumed. However, it should be pointed out that the energy (linear) and volume (linear) mean squares are extremely large compared to the size of the interaction mean square. This difference in size of the mean square indicates that although the energy x volume interaction is highly significant statistically, it is



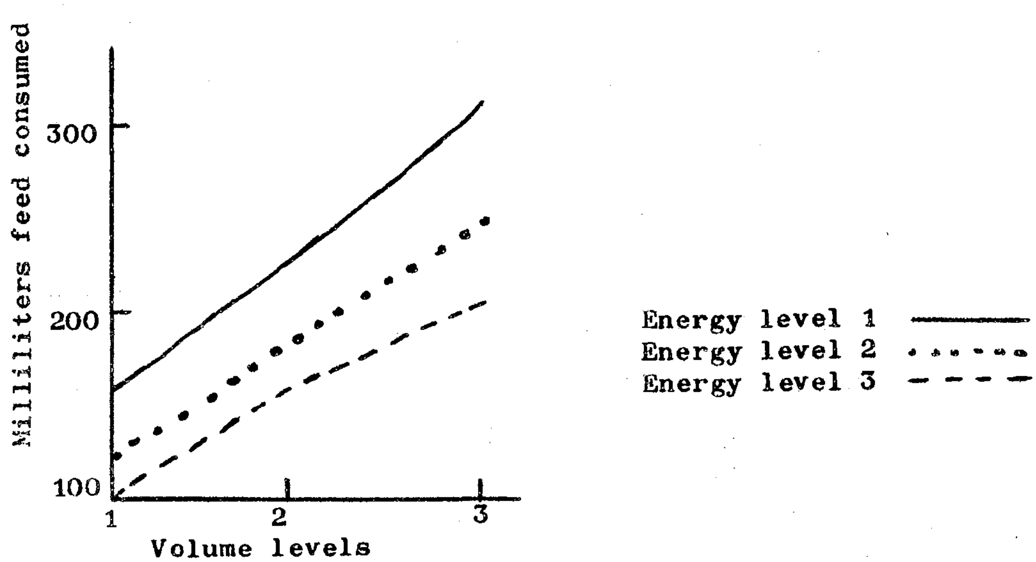


Figure 1

Overall effects of energy and volume upon feed volume consumed, Phase 2 relatively unimportant when compared to the energy and volume linear mean squares. Consequently, the energy and volume main effects will be discussed individually. The size of the energy quadratic mean square is smaller than the interaction mean square; therefore it will not be discussed.

Dietary protein level produced a significant difference in feed volume consumed during periods 6, 9, and 10 only. This difference was significant at the one percent level of probability during periods 9 and 10 and at the five percent level during period 6 (Table XVIII). From the protein main effect means shown in Table XX, it may be seen that during periods 9 and 10, pullets on dietary protein level 2 consumed more volume than did pullets on dietary protein level 1. A reverse trend was significant during period 6. Feed volume consumed due to protein level is related to and follows the same pattern as feed weight consumed, which has been discussed in the previous section.

The dietary energy levels used in this experiment produced a difference in feed volume consumed such that the linear trend was significant at the one percent level of probability during every period and overall for phase 2. The quadratic effects of energy were significant at the one percent level of probability during periods 6, 7, 8, and overall and at the five percent level during periods 9 and 10. The means in Table XX show that as the dietary energy level increases, volume consumption decreases. This is consistent with the accepted fact that chickens eat primarily to meet their energy requirements.

TABLE XX

MAIN EFFECT MEANS OF FEED VOLUME CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 2

	Periods						
	5	6	7	8	9	10	Overall 5-9
Dietary protein level		*			**	**	
1	168.0	191.0	201.8	205.9	217.3	229.7	196.8
2	164.0	187.1	203.3	208.2	228.7	241.5	198.3
Dietary energy level	(L)**[3]	(L)** (Q)**[4]	(L)** (Q)**	(L)** (Q)**	(L)** (Q)*	(L)** (Q)*	(L)** (Q)**
1	194.8	228.8	246.7	252.1	275.4	287.8	239.6
2	161.9	183.9	193.9	201.2	216.6	228.8	191.5
3	141.3	154.5	167.0	167.8	177.0	190.2	161.5
Dietary volume level	(L)**	(L)**	(L)**	(L)**	(L)**	(L)**	(L)**
1	115.8	127.5	138.6	143.5	150.7	159.9	135.2
2	164.4	188.1	203.1	204.5	225.9	234.7	197.2
3	217.8	251.5	265.9	273.1	292.5	312.3	260.2

[1] All means are expressed in average milliliters per bird per day.

[2] Overall based on combined data for periods 5 through 9.

[3] Linear significance

[4] Quadratic significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

The three levels of dietary volume studied showed a linear response in volume consumed which was significant at the one percent level of probability during every period and overall for phase 2. This was expected because as dietary volume increases, volume consumption must increase in order for the pullets to approach their nutrient requirements. In other words, as dietary volume increases, nutrient density decreases.

Energy Consumed

The mean squares for energy consumed are shown in Table XXI. Inspection of this table reveals that no significant interactions occurred during this phase.

A difference in energy consumption due to dietary protein level was significant at the five percent level of probability during period 6 and at the one percent level during periods 9 and 10. The statistical differences and the protein main effect means (Table XXII) follow the same pattern as feed weight consumption on these two dietary protein levels. It appears that with isocaloric rations, the dietary protein level which resulted in the greatest feed weight consumption during any period would proportionately result in the greatest energy consumption. Therefore, the results obtained on each dietary protein level were expected because of the feed weight consumption data reported in a previous section.

The effect of dietary energy level upon energy consumption produced a difference which was significant only during period 5. This significant difference apparently occurred before the pullets

TABLE XXI

ANALYSES OF VARIANCE OF ENERGY CONSUMED FOR EACH PERIOD AND OVERALL[1], PHASE 2

Source of variation	df	Mean squares for the following periods 5	6	7	8	9	10	Overall 5-9
Total (corrected)	233							
Treatment /	17							
Protein (P)	1	1,228	1,255*	5	83	9,939**	7,323**	72
Energy (E)	(2)							
E_L	1	8,554**	258	624	<1	2,205	49	299
E_Q	1	240	73	1,864	35	194	777	325
Volume (V)	(2)							
V_L	1	4,634**	306	3,138*	4,779**	1,851	1,353	2,635**
V_Q	1	717	122	8	1,373	479	186	113
Interactions	(12)							
P x E	2	265	165	262	60	1,531	851	63
P x V	2	423	147	368	729	276	1,648	141
E x V	4	537	297	252	177	914	2,457	331
P x E x V	4	269	132	151	916	1,017	1,371	244
Error	216	533	198	528	458	965	1,024	271

[1]Overall based on combined data for periods 5 through 9.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XXII

MAIN EFFECT MEANS OF ENERGY CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 2

	Periods						
	5	6	7	8	9	10	Overall 5-9
Dietary protein level		*			**	**	
1	173.9	195.8	207.7	211.9	221.2	235.3	202.1
2	169.3	191.2	208.0	213.1	234.3	246.5	203.2
Dietary energy level	(L)**[3]						
1	164.9	192.6	207.9	212.8	232.1	242.7	202.1
2	170.1	192.7	203.9	212.0	226.5	238.3	201.0
3	179.7	195.2	211.9	212.8	224.6	241.6	204.8
Dietary volume level	(L)**		(L)*	(L)**			(L)**
1	178.3	195.4	212.5	219.8	230.2	244.4	207.2
2	169.1	192.5	207.7	209.1	229.8	239.6	201.6
3	167.4	192.6	203.5	208.7	223.3	238.6	199.0

[1]All means are expressed in average Calories of energy consumed per bird per day.

[2]Overall based on combined data for periods 5 through 9.

[3]Linear significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

adjusted to the graded energy levels which were imposed on them at the beginning of period 5.

The lack of significant differences in energy consumption during all periods except 5 show rather conclusively that energy is the most important factor in regulating feed consumption. The pullets in this experiment consumed approximately equal Calories of energy, regardless of their dietary energy level. In other words, they ate until their energy requirement had been satisfied.

Dietary volume level produced a difference in energy consumption which was significant during periods 5, 8 and overall at the one percent level of probability and during period 7 at the five percent level. This pattern of significant differences, as well as the main effect means (Table XXII) follow the pattern of feed weight consumption (see Tables XVI and XVII) for the same reason as dietary protein discussed earlier in this section.

Protein Consumed

From the mean squares for protein consumed (Table XXIII), it may be seen that a significant protein x energy interaction occurred overall and during periods 6, 7, 8 and 9. The overall mean effects for the dietary protein and dietary energy levels are shown in Table XXIV. Examination of the graphic presentation of these means shown in Figure 2 reveals that protein consumption plotted against dietary energy approaches a linear effect at dietary protein level 1 compared to a more quadratic effect for protein level 2.

In view of the overall protein x energy interaction, it is

TABLE XXIII

ANALYSES OF VARIANCE OF PROTEIN CONSUMED FOR EACH PERIOD AND OVERALL[1], PHASE 2

Source of variation	df	Mean squares for the following periods						
		5	6	7	8	9	10	Overall 5-9
Total (corrected)	233							
Treatment	17							
Protein (P)	1	464**	631**	903**	967**	1,508**	1,572**	860**
Energy (E)	(2)							
E_L	1	639**	1,257**	1,268**	1,425**	1,663**	1,626**	1,223**
E_Q	1	17*	24**	48**	23**	36**	39**	29**
Volume (V)	(2)							
V_L	1	22**	2	13*	20**	8	3	11**
V_Q	1	6	1	1	7	3	1	1
Interactions	(12)							
P x E	2	1	14**	19**	18**	17*	9	12**
P x V	2	2	1	1	1	2	4	<1
E x V	4	3	2	1	1	5	11	2
P x E x V	4	2	1	<1	5	6	7	1
Error	216	3	1	2	2	4	4	1

[1]Overall based on combined data for periods 5 through 9.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XXIV

OVERALL[1] MEANS FOR THE EFFECT OF PROTEIN AND ENERGY UPON PROTEIN CONSUMED[2], PHASE 2

Dietary protein level	Dietary energy level[3]		
	1	2	3
1	15.00	12.03	10.13
2	19.70	15.59	13.36

[1]Overall based on combined data for periods 5 through 9.

[2]All means are expressed as grams per bird per day.

[3]See Table I for the dietary equivalents of levels 1, 2 and 3 for protein and energy.

recognized that care must be exercised in discussing the energy and protein main effects. However, it should be noted that both mean squares for protein and energy linear are extremely large when compared to the interaction mean squares. Therefore, it is felt that the significant protein and linear energy effects may be discussed with a reasonable amount of confidence. In contrast, the quadratic energy mean square is relatively small compared to the interaction mean square. Nevertheless, it appears that there is definitely a quadratic effect present.

Dietary protein level resulted in a difference in protein consumption which was highly significant for the overall analysis as well as every period of phase 2 (Table XXIII). From the protein main effect means (Table XXV), it may be seen that as dietary protein was increased, protein intake was increased. These results were expected and are in agreement with the work of Gleaves (1965) and other workers.

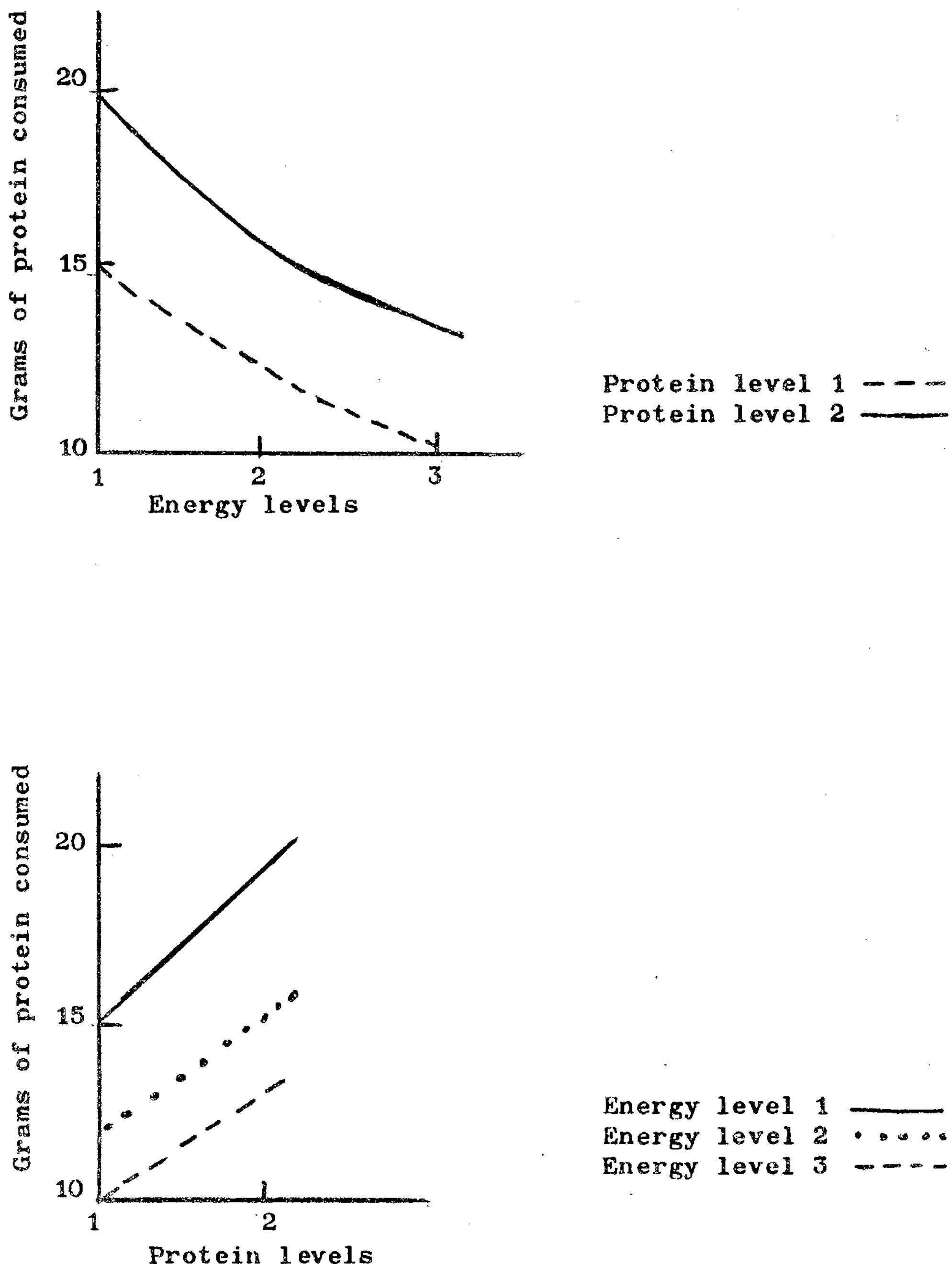


Figure 2

Overall effects of protein and energy upon protein consumed, Phase 2

TABLE XXV

MAIN EFFECT MEANS OF PROTEIN CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 2

	Periods						
	5	6	7	8	9	10	Overall 5-9
Dietary protein level	**	**	**	**	**	**	**
1	11.3	12.8	12.6	12.8	12.4	13.2	12.4
2	14.1	16.0	16.5	16.9	17.5	18.4	16.2
Dietary energy level	(L)**[3] (Q)*[4]	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**	(L)** (Q)**
1	14.9	17.5	17.7	18.1	18.5	19.3	17.3
2	12.3	14.0	13.9	14.4	14.4	15.2	13.8
3	10.9	11.8	12.0	12.1	12.0	12.9	11.7
Dietary volume level	(L)**		(L)*	(L)**			(L)**
1	13.2	14.5	14.8	15.4	15.1	16.0	14.6
2	12.5	14.3	14.5	14.6	15.1	15.7	14.2
3	12.4	14.3	14.3	14.6	14.7	15.7	14.1

[1]All means are expressed in average grams of protein consumed per bird per day.

[2]Overall based on combined data for periods 5 through 9.

[3]Linear significance

[4]Quadratic significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

As either dietary energy or dietary volume was increased, protein consumption was significantly decreased. Similar findings were reported in work with laying hens by Gleaves (1965). However, it may be seen by observing the energy and volume main effect means that with the dietary levels used in this experiment, dietary energy was more effective in spreading the range of protein intake than was dietary volume or dietary protein (see Table XXV). The difference in protein intake produced by dietary energy may be responsible for the significant difference due to energy which will be reported during phase 3.

As was reported in a previous section, dietary volume lost its effect during periods 9 and 10. This points out again that the pullets fed dietary volume levels 2 and 3 appear to have outgrown the constant or fixed dietary volume levels used in this experiment. It was surmised that during periods 9 and 10 some pullets were able to consume large enough volumes of feed to offset any significant differences in protein consumption.

Body Weight Gain

The mean squares for body weight gain, for each period and overall for phase 2 are shown in Table XXVI. Inspection of these mean squares reveals that two different interactions were each significant during an isolated period. However, these will not be discussed because there were no significant overall interactions.

The effect of dietary protein upon body weight gain produced a significant difference during periods 5, 9 and 10. Pullets on dietary protein level 1 gained more weight during periods 5, 6,

TABLE XXVI

ANALYSES OF VARIANCE OF BODY WEIGHT GAIN FOR EACH PERIOD AND OVERALL[1], PHASE 2

Source of variation	df	Mean squares for the following periods						
		5	6	7	8	9	10	Overall 5-9
Total (corrected)	233							
Treatment	17							
Protein (P)	1	7,674**	1,806	438	124	18,828**	22,686**	25
Energy (E)	(2)							
E_L	1	3,138	578	467	2,005	7,339*	2,706	3,700
E_Q	1	2,589	68	1,693	5	<1	1,882	12,434
Volume (V)	(2)							
V_L	1	18,517**	3,609*	10,337**	5,910	13,667**	4,524	241,677**
V_Q	1	94	45	3	6,482	11	3,349	10,632
Interactions	(12)							
P x E	2	1,745	381	147	805	3,969	1,221	11,997
P x V	2	4,631**	106	1,341	1,279	1,600	2,834	19,877
E x V	4	761	1,358	288	598	2,797	951	9,073
P x E x V	4	1,415	1,350	4,554**	1,192	1,196	1,547	10,918
Error	216	979	783	1,069	1,462	1,911	2,056	7,734

[1] Overall based on combined data for periods 5 through 9.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

and 7 than did pullets on dietary protein level 2 (Table XXVII). However, the body weight gain differences during periods 6 and 7 were not significant; nevertheless, the trend was present. This trend was reversed during periods 8, 9 and 10. The overall mean squares infer that there was no significant difference in body weight gain. From observation of the overall protein main effect means, this is apparent, because pullets on both levels of protein gained approximately equal amounts of body weight.

During all periods of phase 2, except period 7, the pullets fed the dietary protein level where the most feed, energy and volume were consumed gained the most weight. The questions may be raised here, did the pullets which gained the most weight do so because of increased feed consumption, or was the genetic potential for a certain growth rate, or some other factor causing the pullets to make faster gains, which necessitated the consumption of more feed? It appears that these questions cannot be answered from the data reported herein.

The significantly larger gains made by pullets fed protein level 1 during period 5 may have been an effort to cancel their body weight deficit which existed at the end of phase 1. The fact that the greatest body weight gain was not made by the pullets consuming the most protein indicates that protein level 1 was as adequate for body weight gains during period 5, and possibly during periods 6, 7 and 8 as was protein level 2. The latter three were periods in which there was no significant differences in body weight gains. Similar findings were reported for period 4 of phase

TABLE XXVII

MAIN EFFECT MEANS OF BODY WEIGHT GAIN[1] FOR EACH PERIOD AND OVERALL[2], PHASE 2

	Periods						
	5	6	7	8	9	10	Overall 5-9
Dietary protein level	**				**	**	
1	210.7	183.7	124.0	126.1	95.6	124.0	739.0
2	199.2	178.1	121.3	127.5	113.5	143.7	739.7
Dietary energy level					(L)*[3]		
1	202.8	179.4	122.8	123.2	111.4	131.7	739.6
2	200.3	180.1	118.9	126.8	104.5	129.8	729.0
3	211.8	183.2	126.3	130.4	97.7	140.0	749.4
Dietary volume level	(L)**	(L)*	(L)**		(L)**		(L)**
1	216.3	186.0	130.8	136.7	113.7	136.5	783.5
2	204.1	180.3	122.7	119.4	104.9	139.2	729.8
3	194.5	176.4	114.5	124.4	95.0	125.8	704.7

[1]All means are expressed in grams.

[2]Overall based on combined data for periods 5 through 9.

[3]Linear significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

1. The reverse body weight gain picture during periods 9 and 10 appear to result from the earlier maturity and higher early egg production of the pullets reared on protein level 2. This indicates an increased protein requirement at this age.

The effect of dietary energy level upon body weight gain produced a statistically significant difference only during period 9 (Table XXVI). The lack of significant differences, excepting period 9, probably resulted from the pullets on all dietary energy levels consuming approximately the same overall amounts of energy (Table XXII). It is interesting to note that the wide range in the levels of protein consumed by the pullets on the three dietary energy levels did not appear to affect body weight gain. Pullets fed dietary energy level 3 consumed the smallest amount of protein but gained the most body weight during phase 2. This would imply that protein was adequate at level 1 and the extra energy produced the extra body weight gains. The body weight gains made by pullets fed the three dietary energy levels are shown graphically in Figure 3. No explanation is offered for the weight gain reversal that occurred during period 9.

Dietary volume showed a significant linear response in body weight gain during periods 5, 6, 7 and 9, and overall. Examination of the dietary volume main effect means (Table XXVII) shows, in general, that as dietary volume level increased, body weight gain decreased. However, this effect appeared more pronounced during the first half of this phase and period 9. This pattern of weight gain is not surprising when consideration is given the fact

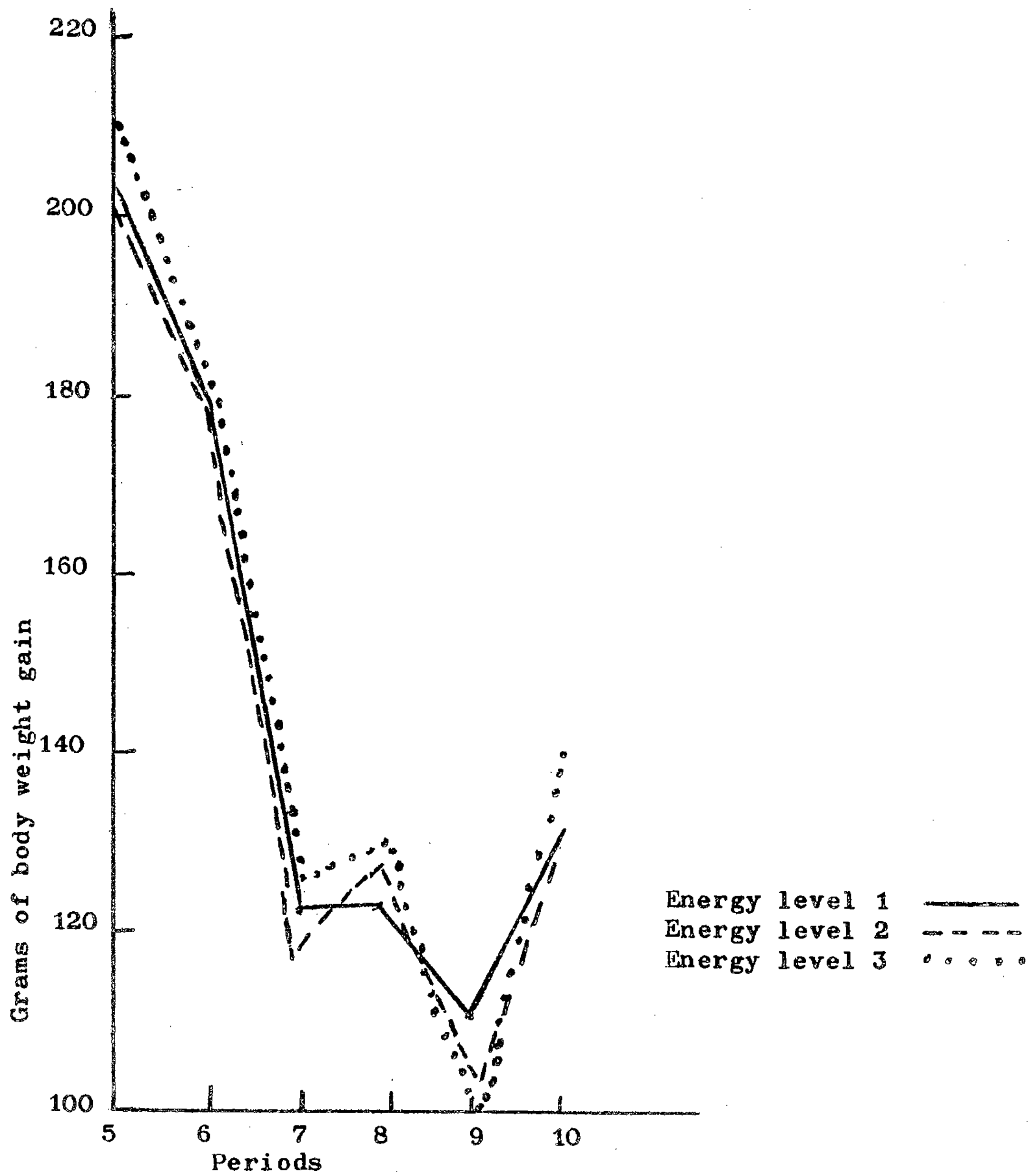


Figure 3

Body weight gain for dietary energy levels, Phase 2

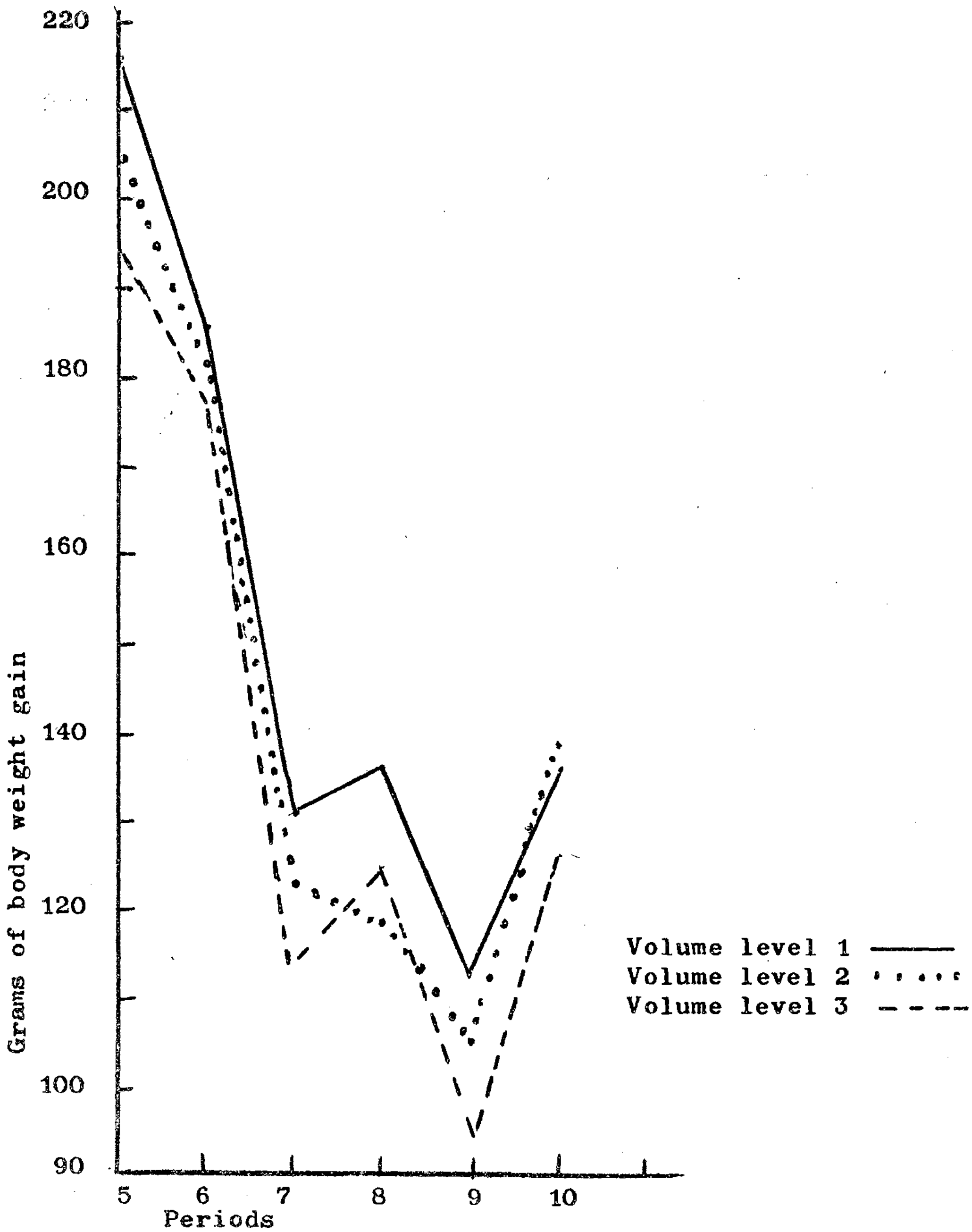


Figure 4

Body weight gain for dietary volume levels, Phase 2 that as dietary volume level increases, actual energy consumption decreases and actual protein consumption decreases slightly in most cases or is equal. It is not known whether the slight increase in actual protein consumption affected body weight gain. The body weight gain for the three dietary levels of volume are shown graphically in Figure 4.

Phase 3

The egg production period from the beginning of the twenty-first week of age to the end of the fortieth week (periods 11 through 20) was included in phase 3. Four pullets died during this phase, three of which were reared on dietary protein level 1 and one on dietary protein level 2. As has been mentioned at the beginning of the discussion of phase 2, missing data were supplied for all dead birds during phase 3. Data on egg numbers and egg weight for period 10 have been included with similar data from phase 3.

The reader should keep in mind that the results observed during phase 3 are the effects of the previous growing treatments imposed during phases 1 and 2. During phase 3, the pullets in all treatments were fed the same laying ration.

Sexual Maturity

The age of the pullet when her first egg was laid was used as the measure of sexual maturity. These data were used to compute the analysis of variance which is shown in Table XXVIII. From examination of the F values in this table, it can be seen readily

TABLE XXVIII

ANALYSIS OF VARIANCE OF DAYS TO FIRST EGG

Source of variation	df	SS	MS	F
Total (corrected)	233	26,294.62		
Treatment	17			
Protein (P)	1	535.54	535.54	4.92*
Energy (E)	(2)			
E_L	1	998.54	998.54	9.18**
E_Q	1	3.18	3.18	0.03
Volume (V)	(2)			
V_L	1	77.54	77.54	0.71
V_Q	1	56.10	56.10	0.52
Interactions	(12)			
P x E	2	669.00	334.50	3.07*
P x V	2	33.95	16.98	0.16
E x V	4	104.64	26.16	0.24
P x E x V	4	317.82	79.46	0.73
Error	216	23,498.31	108.79	

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

that a protein x energy interaction was significant at the five percent level of probability. The means for days to first egg as determined by levels of dietary energy and dietary protein are shown numerically in Table XXIX and graphically in Figure 5.

TABLE XXIX

MEANS FOR THE EFFECTS OF PROTEIN AND ENERGY UPON DAYS TO FIRST EGG

Dietary protein level	Dietary energy level 1	2	3
1	151.6	157.7	160.4
2	153.4	152.6	154.7

A study of these means points out that pullets fed dietary protein level 1 show a greater difference between dietary energy levels, in the number of days to the first egg, than do pullets reared on dietary protein level 2. It is interesting to note that pullets on the combination of dietary protein level 1 and dietary energy level 1 matured more quickly than did any other group of pullets. The next pullets to mature were those fed the combination of dietary protein level 2 and dietary energy level 2. The average amounts of protein and energy consumed, overall, during the growing period, phase 2, at various levels of dietary energy and dietary protein, are shown in Table XXX, to aid in interpreting these results.

All pullets consumed approximately the same number of Calories in contrast to the consumption of various intakes of protein. Note

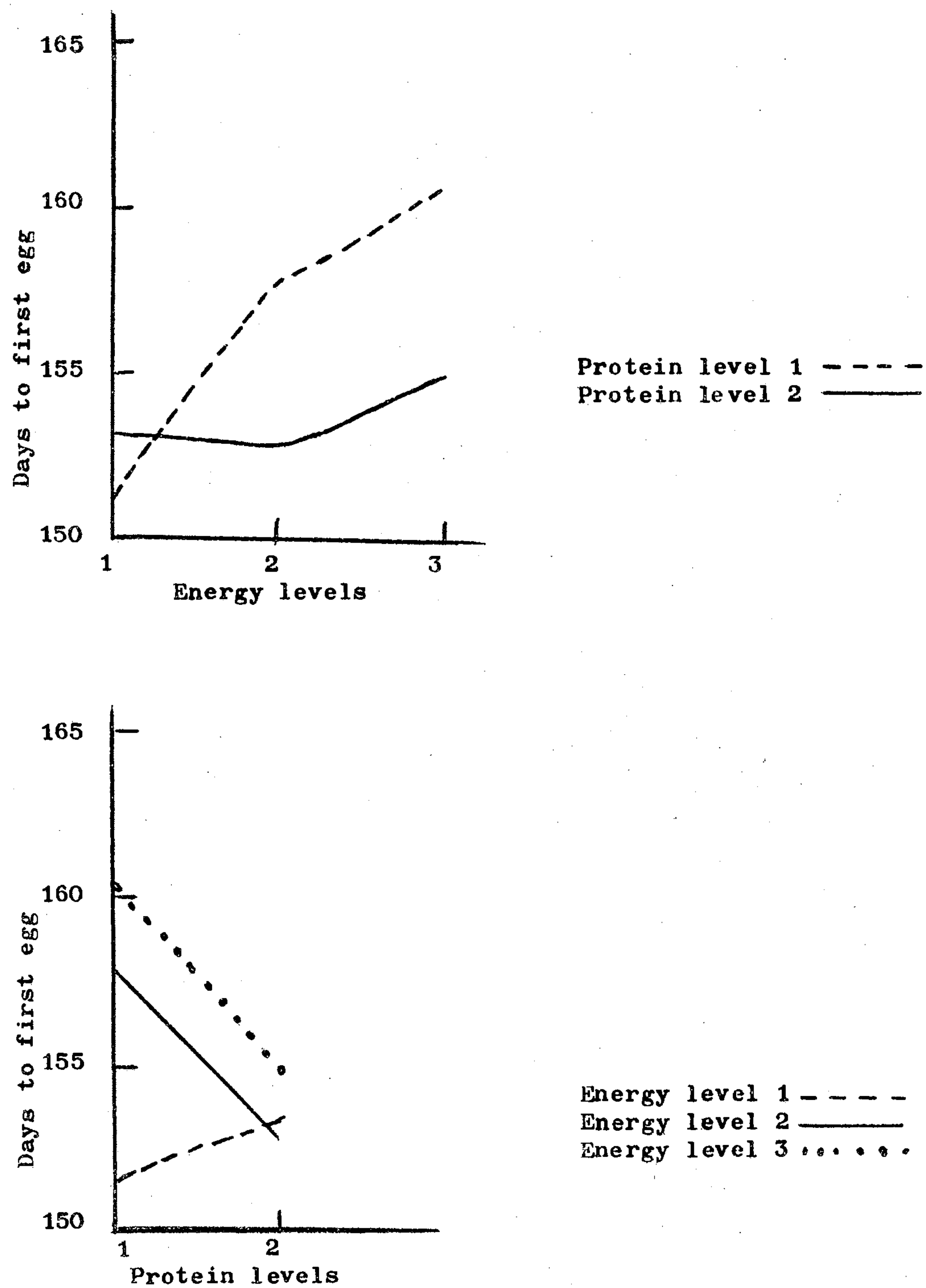


Figure 5

Effects of protein and energy upon days to first egg

TABLE XXX

OVERALL[1] PROTEIN[2] AND ENERGY[3] CONSUMED FOR VARIOUS DIETARY LEVELS OF PROTEIN AND ENERGY AND DAYS TO FIRST EGG, PHASE 2

Dietary energy level	Dietary protein level 1			Dietary protein level 2		
	Protein	Energy	Days to 1st egg	Protein	Energy	Days to 1st egg
1	15.0	201.3	151.6	19.7	201.4	153.4
2	12.0	203.5	157.7	15.6	202.9	152.6
3	10.1	200.5	160.4	13.4	206.2	154.7

[1]Overall based upon combined data for periods 5 through 9.

[2]Expressed in grams per bird per day.

[3]Expressed in Calories per bird per day.

that neither the pullets which consumed the highest nor the lowest level of protein matured earliest. The earliest date of maturity occurred with pullets on either level of dietary protein whose actual protein intake was 15.0 or 15.6 grams. These protein intakes were accompanied by earlier maturity under these conditions where energy intakes ranged between 201 and 206 Calories, as reported in Table XXX. This would lead to the conclusion that neither protein nor energy consumption independently affects the date of sexual maturity. It also illustrates vividly the importance of having the proper calorie-protein ratio. With this in mind, the fact that there was a significant protein x energy interaction on days to first egg is not surprising.

From the overall data in Table XXX it may be seen that, within the range of 201 to 206 Calories on energy intake, growing pullets whose actual protein intake was 12.0 and 10.1 grams, respectively, matured more slowly than did pullets which consumed larger amounts of protein. This confirms the report by Harms (1962) that low-protein diets will delay the sexual maturity of growing pullets.

As may be seen in Table XXVIII, dietary protein and dietary energy levels produced significant differences in date of sexual maturity. The main effect means for days to first egg are shown in Table XXXI. The total difference in days to first egg between the pullets fed dietary energy level 1 and dietary energy level 3 is greater than the difference between the two dietary protein levels. However, as has been previously shown, during phase 2, dietary energy levels produced a greater difference in actual protein consumption than did the dietary protein levels. During the same periods there was no significant difference in energy consumption (Tables XXII and XXV). This appears to infer that the differences among dates of sexual maturity brought about by dietary energy level are really the result of differences in protein consumption on the various levels of dietary energy imposed during phase 2.

Feed Weight Consumed

From the individual period and overall mean squares for feed weight consumed (Table XXXII), the only overall significant difference which may be seen is the energy linear main effects. In addition, energy linear was significant during periods 11, 13, 15, and 18. It may be seen in the overall main effect means, shown in Table XXXIII, that pullets reared on dietary energy level 1

TABLE XXXI

MAIN EFFECT MEANS OF DAYS TO FIRST EGG

	Average number of days to first egg
Dietary protein level	*
1	156.6
2	153.6
Dietary energy level	(L)**
1	152.5
2	155.2
3	157.6
Dietary volume level	
1	154.7
2	154.4
3	156.1

consumed approximately 4 grams more feed per bird per day than did pullets reared on dietary energy levels 2 or 3. Were the pullets fed dietary energy level 1 overconsuming the laying ration because of low energy intakes during the growing period, as has been suggested by research work reported in the literature review? It is obvious from the data reported in this study that the explanation given by other research workers is not true. By referring to Table XXII, it may be seen that there was no significant difference in energy consumption due to dietary energy level, overall or during period 10 of phase 2.

A more likely explanation for the increased energy consumption of pullets reared on dietary energy level 1 is the fact that

TABLE XXXII

ANALYSES OF VARIANCE OF FEED WEIGHT CONSUMED FOR EACH PERIOD AND OVERALL[1], PHASE 3

Source of variation	df	Mean squares for the following periods										
		11	12	13	14	15	16	17	18	19	20	Overall 11-20
Total (corrected)	233											
Treatment	17											
Protein (P)	1	25	242	148	9	459	358	281	267	215	155	61
Energy (E)	(2)											
E_L	1	4,092**	640	1,275*	359	913*	117	402	935*	340	72	637**
E_Q	1	163	79	153	129	209	<1	69	5	477	219	142
Volume (V)	(2)											
V_L	1	3,422**	97	365	57	25	3	2	137	66	685*	107
V_Q	1	8	<1	<1	29	1	210	2	425	1	400	32
Interactions	(12)											
P x E	2	273	94	87	191	201	159	34	86	236	202	3
P x V	2	33	212	38	142	14	183	50	611	109	40	28
E x V	4	73	167	99	61	96	270	184	17	366	96	30
P x E x V	4	116	274	181	153	252	113	146	207	357	10	55
Error	216	176	241	214	146	154	203	118	211	221	143	82

[1]Overall based on combined data for periods 11 through 20.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XXXIII

MAIN EFFECT MEANS FOR FEED WEIGHT CONSUMED[1] FOR EACH PERIOD AND OVERALL[2], PHASE 3

	Periods										
	11	12	13	14	15	16	17	18	19	20	Overall 11-20
Dietary protein level											
1	97.1	88.0	97.4	102.5	108.6	105.8	107.0	109.4	106.7	100.7	102.4
2	96.5	90.1	99.0	102.9	105.8	108.3	109.2	111.5	108.6	102.3	103.4
Dietary energy level	(L)[3]**		(L)*		(L)*			(L)*			(L)**
1	102.5	91.5	101.7	104.7	110.3	107.9	110.1	112.8	110.1	102.9	105.4
2	95.6	88.2	97.1	101.6	105.9	107.1	107.3	110.7	105.6	100.2	101.8
3	92.3	87.4	95.9	101.7	105.5	106.2	106.9	107.9	107.2	101.5	101.4
Dietary volume level	(L)**									(L)*	
1	92.0	88.3	96.7	102.3	107.6	107.6	108.0	112.4	108.3	100.4	102.3
2	97.1	89.1	98.2	102.2	107.1	105.7	108.5	108.6	107.5	99.7	102.4
3	101.4	89.8	99.8	103.5	106.9	107.9	107.7	110.5	107.0	104.6	104.0

[1]All means are expressed in grams consumed per bird per day.

[2]Overall based on combined data for periods 11 through 20.

[3]Linear significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

they matured earlier, produced more eggs, and gained more body weight than did pullets fed dietary energy levels 2 or 3. Egg production and body weight gain will be discussed in more detail later. The differences in feed weight consumption due to the dietary energy levels fed during the rearing period were greater when the pullets were first placed on the laying ration at 20 weeks of age. However, these differences did persist to a lesser degree throughout the entire 20-week egg production period (Table XXXIII).

Levels of dietary volume produced a significant difference in feed weight consumed during periods 11 and 20. Preceding period 11, pullets fed dietary volume levels 2 and 3 were accustomed to consuming significantly larger volumes of feed than those pullets fed dietary volume level 1 (Table XX). Within two weeks after the ration change was made, the pullets on dietary volume levels 2 and 3 were consuming less feed volume. No explanation, other than chance, is apparent for the significant difference in the feed weight consumption which occurred due to dietary volume during period 20.

Feed Volume, Energy, and Protein Consumed

The overall mean squares and overall main effect means for the feed volume, energy and protein consumption are shown in Table XXXIV and Table XXXV, respectively. It is obvious that since all birds were fed the same ration during phase 3, groups of pullets which consumed the most feed weight would by the same token consume the most feed volume, energy and protein. Therefore, this is the reason why the energy linear is significant for each of

TABLE XXXIV

ANALYSES OF VARIANCE OF FEED VOLUME, ENERGY, AND PROTEIN CONSUMED, OVERALL[1], PHASE 3

Source of variation	df	Mean squares for: Feed volume	Energy	Protein
Total (corrected)	233			
Treatment	17			
Protein (P)	1	170	435	1
Energy (E)	(2)			
E_L	1	1,782**	4,490**	14**
E_Q	1	400	1,033	3
Volume (V)	(2)			
V_L	1	307	786	2
V_Q	1	9	226	1
Interactions	(12)			
P x E	2	10	6	1
P X V	2	8	198	1
E x V	4	6	216	1
P x E x V	4	153	396	1
Error	216	228	586	2

[1]Overall based on combined data for periods 11 through 20.

**Significant at the one percent level of probability.

TABLE XXXV

OVERALL[1] MAIN EFFECT MEANS FOR FEED VOLUME, ENERGY, AND PROTEIN CONSUMED, PHASE 3

		Volume[2]	Energy[3]	Protein[4]
Dietary protein level				
	1	171.4	274.3	15.0
	2	173.1	277.0	15.1
Dietary energy level		(L)**[5]	(L)**	(L)**
	1	176.5	282.5	15.4
	2	170.4	272.6	14.9
	3	169.8	271.7	14.9
Dietary volume level				
	1	171.3	274.1	15.0
	2	171.3	274.2	15.0
	3	174.0	278.6	15.2

[1]Overall based on combined data for periods 11 through 20.

[2]Expressed in milliliters of feed per bird per day.

[3]Expressed in Calories of energy per bird per day.

[4]Expressed in grams of protein per bird per day.

[5]Linear significance

**Significant at the one percent level of probability.

these factors and why the main effect means follow the same pattern as the main effect means for feed weight consumed.

Egg Production

The individual period and overall mean squares for egg production are shown in Table XXXVI. The overall mean squares from this table reveal that the effects of dietary protein produced a difference in egg production which was significant at the five percent level of probability. Examination of the dietary protein main effect means for egg production, shown in Table XXXVII, indicates that the overall difference was brought about largely by the increased egg production during periods 11 and 12. This seems to denote that protein consumption during the growing period is a critical factor for pullets which have been fed a below-average protein diet during the growing period. Low-protein diets fed during the growing period reduced egg production early in the laying year, but when pullets were placed on a high quality laying ration, they soon overcame this handicap, provided it was not overly severe. It is assumed that dietary protein level 1 used in this experiment did not result in a severe protein deficiency.

The overall egg production means for the dietary protein main effects (Table XXXVII) reveal that pullets reared on dietary protein level 2 produced an average of 3.3 more eggs than did pullets reared on dietary protein level 1. It is believed that this significant difference in egg production was brought about by the fact that the pullets on dietary protein level 2 consumed significantly more protein, during every period of phases 1 and 2, than did

TABLE XXXVI

ANALYSES OF VARIANCE OF EGG PRODUCTION FOR EACH PERIOD AND OVERALL[1], PHASE 3

Source of variation	df	Mean squares for the following periods: 10	11	12	13	14	15	16	17	18	19	20	Overall 10-20
Total (corrected)	233												
Treatment	17												
Protein (P)	1	<.01	52.09*	154.76**	15.23	1.22	1.42	1.74	0.06	1.68	0.80	2.18	636.74*
Energy (E)	(2)												
E_L	1	1.31	82.22**	230.67**	6.65	2.30	0.05	2.10	0.23	6.30	2.34	1.62	1,289.44**
E_Q	1	0.40	1.76	13.24	0.22	5.02	1.92	0.10	0.48	0.02	0.81	2.46	33.24
Volume (V)	(2)												
V_L	1	0.21	6.33	20.61	2.17	1.41	2.82	0.00	2.70	2.66	5.63	0.37	0.32
V_Q	1	0.04	12.41	9.11	46.93*	2.27	0.95	1.74	0.03	0.51	3.14	9.82	68.46
Interactions	(12)												
P x E	2	2.22*	14.96	27.70	7.70	0.54	2.76	0.94	3.42	3.19	2.18	13.98*	23.75
P x V	2	0.01	9.37	5.93	10.76	7.71*	1.05	0.39	0.32	2.54	11.39**	5.39	191.62
E x V	4	0.02	11.96	8.05	0.18	2.74	0.54	1.43	0.82	0.22	0.85	8.95	44.39
P x E x V	4	0.05	10.21	14.49	8.91	1.76	5.97*	2.68	2.95	1.57	3.43	3.95	263.13
Error	216	0.56	10.86	20.59	8.74	2.31	1.85	2.12	2.16	2.47	2.31	4.20	149.32

[1]Overall based on combined data for periods 10 through 20.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XXXVII

MAIN EFFECT MEANS FOR EGG PRODUCTION FOR EACH PERIOD AND OVERALL[1], PHASE 3

	Periods										
	10	11	12	13	14	15	16	17	18	19	20	Overall 10-20
Dietary protein level		*	**									*
1	0.1	1.7	6.7	10.8	11.9	12.0	12.2	11.8	11.4	11.2	10.8	100.8
2	0.1	2.7	8.3	11.3	12.0	11.8	12.0	11.9	11.6	11.3	11.0	104.1
Dietary energy level		(L)[2]**	(L)**									(L)**
1	0.2	2.9	8.9	11.3	12.2	12.0	12.2	11.9	11.7	11.4	11.0	105.6
2	0.2	2.3	7.2	11.1	11.8	11.8	12.1	11.8	11.5	11.2	11.1	101.9
3	0.0	1.4	6.5	10.8	11.9	11.9	12.0	11.8	11.3	11.2	10.8	99.9
Dietary volume level				(Q)[3]*								
1	0.2	2.3	7.0	10.6	12.0	12.0	12.1	11.7	11.7	11.5	11.0	102.1
2	0.1	2.5	7.8	11.7	12.1	12.0	12.0	11.9	11.5	11.1	10.6	103.2
3	0.1	1.9	7.7	10.9	11.8	11.7	12.1	12.0	11.4	11.1	11.1	102.1

[1]Overall based on combined data for periods 10 through 20.

[2]Linear significance

[3]Quadratic significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

pullets fed dietary protein level 1.

It may be seen from the overall mean squares in Table XXXVI that due to the linear energy effects there were differences in egg production which were significant at the one percent level of probability. In Table XXXVII, the energy main effect means indicate that the difference in egg production was due largely to the early egg production in periods 11 and 12. This is similar to the effects of dietary protein shown in the same table.

As a check to see whether energy is responsible for this difference in egg production, an inspection of nutrient consumption during phase 2 should be helpful. From Table XXII, it may be seen that there was no significant difference in energy consumption during phase 2, while at the same time there was a significant difference in protein consumption. It appears that different protein consumptions during phase 2, brought about by the dietary energy level, is the reason for the significant difference in egg production on the three dietary energy levels. In other words, energy is acting indirectly through protein to produce a difference in egg production. The energy main effect means show approximately a two to three egg difference between each dietary energy level.

It appears that a large part of the difference in egg production for the levels of dietary protein or dietary energy result from egg production starting earlier. In other words, as the age of sexual maturity decreases, egg production increases.

Egg Weight

The mean squares for egg weight are shown for each period and overall in Table XXXVIII. Differences in egg size were not significant overall, but protein and energy treatments show a significant difference during periods 11 and 12. From the main effect means, shown in Table XXXIX, it may be seen that the pullets fed dietary protein level 1 laid slightly heavier eggs than did pullets fed dietary protein level 2. The reverse was true for pullets fed different levels of dietary energy. The pullets fed dietary energy level 1 consumed more protein during phase 2, and laid heavier eggs than did pullets fed dietary energy levels 2 or 3 where protein consumption was significantly lower.

The pullets fed dietary energy or dietary protein levels that resulted in the lowest egg weight produced the greatest number of eggs (Tables XXXVII and XXXIX). Level of dietary volume produced a statistically significant difference in egg size during periods 15, 17, 18, and 19. During these periods the means show that as dietary volume increased, egg size decreased.

Body Weight Gain

The analyses of variance for body weight gain are shown in Table XL. By examining the mean squares in this table, it may be seen that a significant protein x energy interaction occurred overall and during period 20. The overall interaction means are shown numerically in Table XLI and graphically in Figure 6. These means show that the body weight of pullets reared on protein level 2 decreased as energy level increased. In contrast, the effects of energy on pullets reared on dietary protein level 1 gave a pronounced quadratic result. No logical explanation is available to

TABLE XXXVIII

ANALYSES OF VARIANCE OF EGG WEIGHT FOR EACH PERIOD AND OVERALL[1], PHASE 3

Source of variation	df	Mean squares for the following periods											
		10	11	12	13	14	15	16	17	18	19	20	Overall 10-20
Total (corrected)	233												
Treatment	17												
Protein (P)	1	10	1,709*	923*	141	4	23	14	3	1	1	1	17
Energy (E)	(2)												
E_L	1	104	4,469**	1,233*	119	<1	6	10	1	12	6	7	1
E_Q	1	96	74	63	25	23	31	20	19	23	9	14	<1
Volume (V)	(2)												
V_L	1	45	69	1	138	90	176*	126	158*	151*	151*	48	10
V_Q	1	8	962	370	94	10	33	25	27	46	21	20	1
Interactions	(12)												
P x E	2	132	196	226	31	7	5	9	12	14	8	13	10
P x V	2	33	568	194	32	5	3	8	3	1	1	8	1
E x V	4	10	386	171	123	19	19	10	18	17	10	17	8
P x E x V	4	34	125	88	50	7	23	33	40	24	34	26	12
Error	216	64	420	250	57	31	33	34	35	36	37	23	7

[1]Overall based on combined data for periods 10 through 20.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XXXIX

MAIN EFFECT MEANS FOR EGG WEIGHT FOR EACH PERIOD AND OVERALL[1], PHASE 3

	Periods											
	10	11	12	13	14	15	16	17	18	19	20	Overall 10-20
Dietary protein level		*	*									
1	42.3	41.7	46.0	48.7	50.8	52.7	54.0	54.4	55.2	55.5	55.8	53.1
2	35.5	41.2	45.8	48.8	50.5	52.1	53.5	54.2	55.1	55.4	55.9	52.6
Dietary energy level		(L)[2]**	(L)*									
1	39.3	42.3	46.3	49.0	50.5	52.4	53.8	54.2	55.2	55.5	55.4	53.0
2	40.0	42.1	46.2	48.8	51.1	52.9	54.1	54.7	55.6	55.8	56.2	52.8
3	29.8	39.8	45.3	48.4	50.4	52.0	53.3	54.0	54.7	55.2	55.9	52.8
Dietary volume level						(L)*		(L)*	(L)*	(L)*		
1	39.8	40.9	45.9	48.8	51.3	53.2	54.4	55.1	55.9	56.3	56.2	53.2
2	36.8	42.0	46.0	48.6	50.9	52.9	54.2	54.8	55.8	55.9	56.2	52.8
3	38.3	41.4	45.8	48.9	49.7	51.1	52.6	53.1	53.9	54.3	55.1	52.7

[1]Overall based on combined data for periods 10 through 20.

[2]Linear significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

TABLE XL

ANALYSES OF VARIANCE OF BODY WEIGHT GAIN FOR EACH PERIOD AND OVERALL[1], PHASE 3

Source of variation	df	Mean squares for the following periods: 11	12	13	14	15	16	17	18	19	20	Overall 11-20
Total (corrected)	233											
Treatment	17											
Protein (P)	1	3,833	89,174**	4,029	99	1,982	1,569	1,595	598	1,182	115	75,744
Energy (E)	(2)											
E_L	1	7,139	16,008	11,618	446	1,232	1,699	2,622	6,104	2,409	4,234	4,989
E_Q	1	2,557	533	3,093	1,538	458	104	1,317	43	1,613	15,155*	96,720*
Volume (V)	(2)											
V_L	1	173,923**	16,743	230	6,084	609	921	177	8,336	1,504	3,103	288,712**
V_Q	1	5,934	4,378	20,061	5,758	3,149	2,132	4,630	3,854	3,024	2,673	9,566
Interactions	(12)											
P x E	2	189	22,800	1,226	1,414	37	188	1,144	726	4,972	20,534**	124,441**
P x V	2	2,454	8,304	581	9,649*	1,376	502	1,436	8	5,867	5,681	6,732
E x V	4	4,541	2,767	6,088	1,164	3,990	3,236	3,347	5,214	2,984	2,704	14,937
P x E x V	4	5,032	2,459	1,940	1,288	1,737	1,090	5,088*	2,737	1,852	838	2,990
Error	216	5,644	8,216	5,571	2,629	2,519	2,986	2,120	2,414	2,233	2,638	25,029

[1]Overall based on combined data for periods 11 through 20.

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

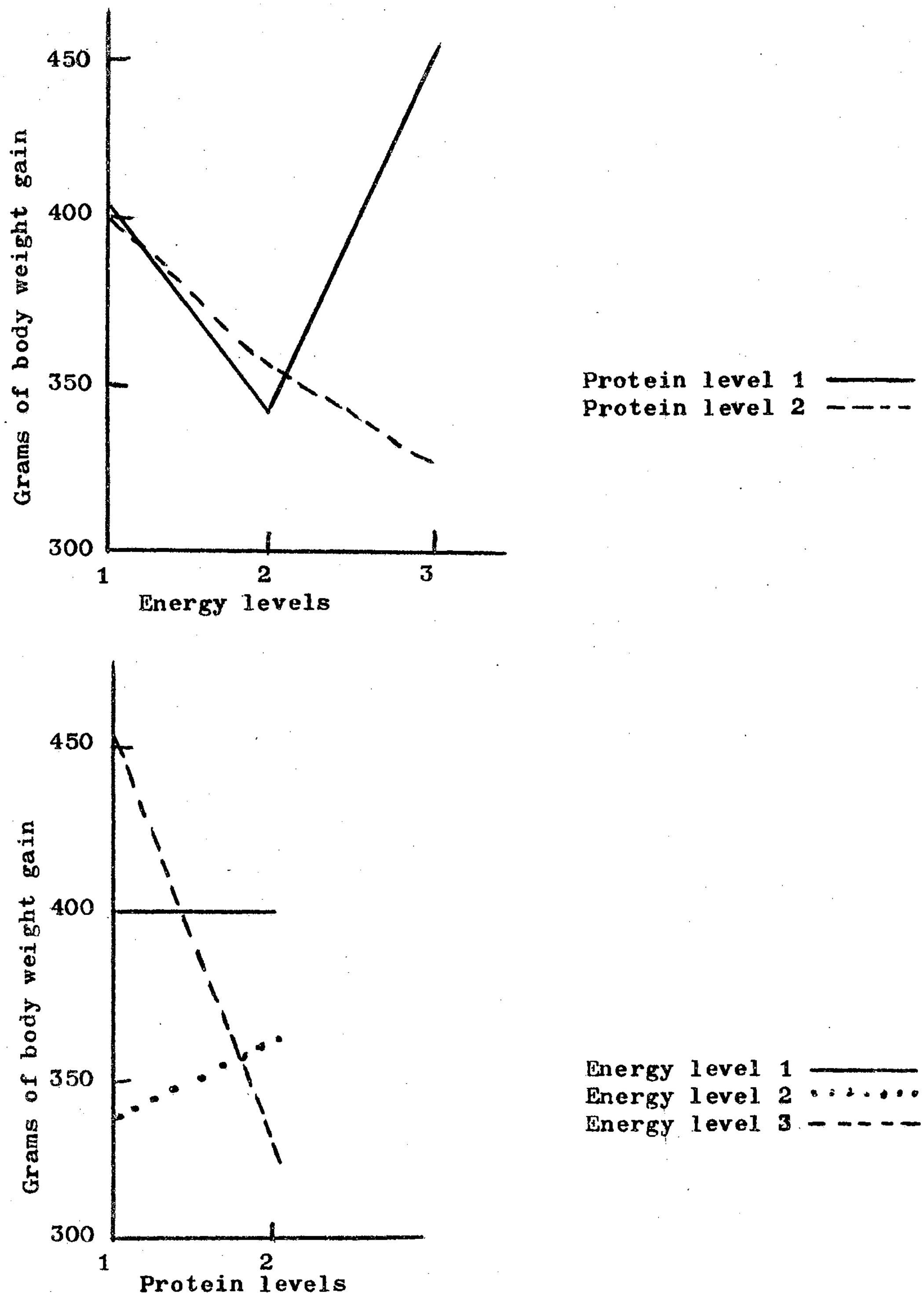


Figure 6

Overall effects of protein and energy upon body weight gain, Phase 3

TABLE XLI

OVERALL[1] MEANS FOR THE EFFECT OF PROTEIN AND ENERGY UPON BODY WEIGHT GAIN[2], PHASE 3

Dietary protein level	Dietary energy level 1	2	3
1	402.4	342.4	454.0
2	400.8	363.3	326.6

[1]Overall based on combined data for periods 11 through 20.

[2]All means are expressed in grams.

explain this interaction.

From the main effect means, shown in Table XLII, it may be seen that dietary energy level produced a quadratic effect which was significant overall and during period 20. In light of the protein x energy interaction just discussed, it is apparent that energy and protein are not operating independently of one another and cannot be discussed individually.

The carryover effects of dietary volume level produced a linear difference in body weight gain which was significant at the one percent level of probability. The main effect means, Table XLII, illustrate the fact that as dietary volume increased, body weight gain increased. Pullets on dietary volume level 3 gained 86 grams more of body weight during phase 3 than did pullets reared on dietary volume level 1. It should be noted that body weight gains for dietary volume levels during phase 2 were the reverse of gains observed in phase 3 (Tables XXVII and XLII).

TABLE XLII

MAIN EFFECT MEANS FOR BODY WEIGHT GAIN[1] FOR EACH PERIOD AND OVERALL[2], PHASE 3

	Periods										
	11	12	13	14	15	16	17	18	19	20	Overall 11-20
Dietary protein level		**									
1	156.1	85.2	-11.3	20.8	54.4	22.0	25.7	27.9	4.5	10.8	399.6
2	148.0	46.1	-3.0	19.5	48.6	27.2	30.9	24.7	9.0	12.2	363.7
Dietary energy level										(Q)[3]*	(Q)*
1	161.1	54.5	4.1	23.6	55.3	28.4	34.1	19.8	8.9	12.0	401.6
2	147.3	67.8	-12.3	16.5	49.5	23.7	24.9	26.9	10.5	0.1	352.8
3	147.6	74.7	-13.2	20.3	49.6	21.8	25.9	32.3	1.0	22.4	390.3
Dietary volume level	(L)[4]**										(L)**
1	122.2	73.0	-1.8	10.4	56.0	20.1	24.1	21.9	7.4	9.5	343.1
2	144.9	71.8	-20.2	27.2	46.3	28.9	34.6	20.6	11.9	6.7	372.5
3	189.0	52.2	0.6	22.9	52.1	24.9	26.2	36.5	1.1	18.4	429.1

[1]All means are expressed in grams of gain per bird.

[2]Overall based on combined data for periods 11 through 20.

[3]Quadratic significance

[4]Linear significance

*Significant at the five percent level of probability.

**Significant at the one percent level of probability.

SUMMARY AND CONCLUSIONS

A completely randomized experiment with a factorial arrangement of treatments was designed to study the effect of feeding two levels of dietary protein, three levels of dietary energy and three levels of dietary volume to commercial egg-type pullets. The two dietary protein levels were fed from the first week to the twentieth week of age, while the dietary energy and dietary volume levels were fed from the ninth to the twentieth week of age. Dietary weight was held constant in all concurrently fed rations. The effects of the treatments imposed during the growing period were studied throughout the subsequent 20-week egg production period. The factors measured during the egg production period were sexual maturity, feed consumption, egg production, egg weight and body weight gain.

Growing Period (Day-old to 20 weeks of age)

The dietary protein levels studied in this experiment resulted in a difference in actual protein consumption which was statistically significant during the entire growing period. In contrast, dietary protein resulted in no significant overall difference in feed weight consumed. Protein requirements appear to be most critical for pullets during the first four weeks of life and just preceding the onset of egg production (17-20 weeks of age).

Dietary energy level resulted in no overall significant difference in energy consumption. This verifies the findings of most research workers that pullets eat primarily to satisfy their energy requirement. In contrast, differences in energy level resulted in significant differences in feed weight consumption. This difference was predominantly linear, but exhibited a small quadratic effect. This indicates that as dietary energy level increases, feed weight consumptien decreases. Along with this difference in feed weight consumption, there was a significant difference in protein intake for each of the three dietary energy levels. Different protein intakes would be expected because each of the various dietary energy levels contained equal amounts of protein per unit of feed.

A positive linear response in feed volume consumption was produced by differences in dietary volume level. These differences were statistically significant during every period that the treatments were imposed. Dietary volume levels produced no difference in feed weight consumption during the 17th to the 20th week of age. This infers that by the time the pullets had reached this age, they had adjusted to the increased dietary volume levels by increasing the volume of their intestines or by outgrowing the volume levels used in this experiment. Dietary volume level produced a significant difference in body weight gain when the pullets were 9 to 18 weeks of age. As the dietary volume level increased, body weight gain decreased.

Egg Production Period (21 to 40 weeks of age)

A dietary protein x dietary energy interaction significantly affected the date of sexual maturity. This interaction resulted primarily from the various protein intakes which occurred during the growing period. Pullets that consumed 15.0 grams of protein per day from 9 to 18 weeks of age reached sexual maturity in 151.6 days. When protein intake was increased to 19.7 grams, there was a delay of 1.8 days in the date of sexual maturity, while decreases in protein intake to 13.4, 12.0 and 10.1 grams were associated with delays in the date of sexual maturity of 3.1, 6.1 and 8.8 days, respectively, above the sexual maturity date of the pullets which consumed 15 grams of protein. All pullets consumed approximately an equal number of Calories during the 9 to 18-week growing period. This illustrates the importance of having the proper calorie-protein ratio in growing pullet diets as related to the date of sexual maturity. These protein intakes are averages over a ten-week growing period. The actual protein needs of growing pullets is certain to vary during this time. This points out the need for intensive studies in this area to determine more precisely the proper intakes and ratios needed by growing pullets.

The dietary energy levels fed during the growing period produced a difference in feed weight consumption during the egg production period. Pullets reared on dietary energy level 1 consumed four more grams of feed per bird per day during the 20-week egg production period than did pullets reared on energy levels 2 and 3. It is believed that the four-gram difference in feed consumption occurred because the pullets reared on dietary energy level 1 laid more eggs and gained more body weight during the egg production period.

Pullets which consumed protein at average daily intakes of 12.4 and 16.2 grams during the 9 to 18-week growing period, produced 100.8 and 104.1 eggs, respectively, during the egg production period. It appears that energy is acting indirectly in affecting egg numbers, since all pullets consumed isocaloric quantities of feed during the growing period. Pullets fed the three dietary energy levels consumed 17.3, 13.8 and 11.7 grams of protein per day and produced 105.6, 101.9 and 99.9 eggs, respectively. This indicates that protein consumed during the growing period was the prime factor determining number of eggs produced during the egg production period.

Pullets which matured earliest laid significantly more eggs than did slow-maturing pullets. No significant differences in egg weight were recorded from the levels of dietary protein, energy or volume used in this experiment.

As dietary volume level, imposed during the growing period, increased, body weight gain increased during the egg production period. This is the reverse of the trend due to the dietary volume levels reported for the growing period. In other words, body weight gains tended to equalize with time and availability of nutrients. Carcass analysis would be helpful in future experiments of this kind to determine whether muscle, skeletal or fatty tissue is formed when egg-type pullets gain at different rates and at different times during the life cycle.

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Master of Science

Thesis: THE RELATIONSHIP OF PROTEIN, ENERGY AND VOLUME INTAKE IN EGG-TYPE CHICKENS DURING THE GROWING PERIOD TO SUBSEQUENT LAYING HOUSE PERFORMANCE

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