THYROID ACTIVITY AS RELATED TO STRAIN DIFFERENCES IN GROWING CHICKENS

By

Edward W. Glazener

Thesis submitted to the Faculty of the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Doctor of Philosophy

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. C. S. Shaffner and Dr. M. A. Jull for their advice and suggestions in conducting the experiment.

Acknowledgments are also made to Lederle Laboratories, Pear River, New York, for supplying the thiouracil, and to Cerophyl Laboratories, Kansas City, Missouri, for supplying the thyroprotein (Protamone).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figures | Page

INTRODUCTION

Experimental work and field observations have indicated that differences among strains of poultry exist with respect to various economic qualities. From the standpoint of broiler production, the poultryman is interested in economy of growth, feed utilization, and feathering. Since the financial return of the commercial poultryman depends upon the production of large quantities of poultry meat, small differences in growth and feed utilization are of real economic value. He is looking to the scientist for knowledge and practices which may result in more efficient production.

Furthermore, the scientist-- geneticist, physiologist, or biochemist-- is interested in these same factors, growth, feed utilization, and feathering, from the fundamental biological viewpoint as well as their application to commercial practices. He is curious to see if living bodies will respond according to his hypotheses that he has formulated from experimentation and study. Often from his work the scientist obtains an indescribable satisfaction from the finding and searching for knowledge, scientific knowledge which in this modern age is rapidly finding its way into medical and commercial practices.

Although the author and several other workers have observed strain differences in growth and feed utilization, little information is available indicating through what mechanism or physiological manner these differences operate. Glazener and Jull (1946) developed broiler strains by genetic selection differing in growth, feed utilization, and feathering. The present study was furthered from the standpoint of the endocrine system, particularly the thyroid gland. This investigation was conducted in an attempt to learn more about the following questions: (1) Is it possible to stimulate growth by the use of the thyroid hormone? (2) Do strains differ in their response to the hormone? (3) Do strains of the same breed differ in thyroid activity?

REVIEW OF THE LITERATURE

Observation has shown that chickens under the same environment may vary considerably in body weight. Funk, Knandel, and Callenbach (1930), in a statistical study of growth in White Leghorns, found that the coefficient of variability at four weeks of age in four different broods varied from 14.6 to 19.4 per cent. Although the variability was less as the birds approached maturity, they found wide differences in individual weights at 16 weeks of age. Asmundson and Lerner (1933) studied the rate of growth from two to eight weeks of age in 340 White Leghorn chicks. These workers concluded that there were genetic differences with respect to rate of growth within the strain of White Leghorns studied, and that these differences in rate of growth were determined by multiple factors. Schnetzler (1936) demonstrated that it was possible to select for rapid and slow-growing birds in Barred Plymouth Rocks. From his selected groups of fast and slow-growing parents, he secured results which indicated the possibility of developing strains differing in growth rate.

Since several investigators observed less variability in the length of the appendicular skeletal bones than in the body weight of the fowl, Glazener and Jull

(1946) developed two strains of New Hampshires and Barred Plymouth Rocks by family selection on the basis of shank length. The long-shanked strains of both breeds grew more rapidly than did the short-shanked strains. Jull and Glazener (1946) found a high positive correlation between body weight and shank length at ten weeks of age.

Much data are available on feed utilization from general growth experiments, managerial studies, and nutritional work. Only a limited amount of data, however, are available on feed utilization in the domestic fowl on a family or strain basis. Morris, Palmer, and Kennedy (1933) with rats indicated genetic differences in feed utilization. By nine generations of selective inbreeding, these workers established two lines. The low-efficiency line was about 40 percent less efficient than the high-efficiency line. Hess, Byerly, and Jull (1941) demonstrated the variability of efficiency between sires. Sires that produced the most efficient purebreds were observed to produce the most efficient crossbreds. Glazener and Jull (1946a) found that the long-shanked strains of New Hampshires and Barred Plymouth Rocks utilized feed better than did the short-shanked strains. McCartney and Jull (1948), by further developing the short and long-shanked New Hampshires into strains A and B, found the strains to differ in feed utilization.

Although the data on feed efficiency from the genetic standpoint are limited, information on differences in strain response and feed efficiency regarding the feeding of hormones to poultry is almost unavailable.

Palmer, Kennedy, Calverley, Lohn, and Weswig (1946), in a biochemical and physiological study of their low and high-efficiency strains of rats, fed anterior pituitary growth hormone to males and females of both strains. The hormone appeared to promote growth and increase feed efficiency in both strains within inherent limits. Strains of rats with a lower order of efficiency were affected less toward the attainment of higher efficiency level than some of the more efficient strains. No effect was exerted on the high-efficiency males. Periodic administration of thyroid reduced the efficiency of male rats of the more efficient strains, but did not significantly affect this characteristic in the less efficient strain. Combined action of castration and thyroid feeding on the efficiency of feed utilization indicated that castration imposed a two-fold hardship on the thyroid-fed rat. Dickerson and Gowen (1947) presented evidence which indicated that the "yellow" gene in mice reduced food requirement per unit of gain. These workers reported that those mice with the "yellow" gene had better efficiency because of increased food intake and reduced energy expended. Citing the work of a German scientist, Maria Weitze (1940), these workers suggest that the action of the "yellow" gene is hormonal, involving altered carbohydrate metabolism.

In the last few years, several workers have reported on various effects of feeding fresh or desiccated thyroid to chickens. Until the last five years, dosage level and potency of the material have not been standardized; therefore, results have been extremely variable. Furthermore, most of the published work has concerned adult stock, the effect on feather pigmentation and reproductive processes.

Crew and Huxley (1923) fed dried thyroid to 12 chickens daily in a wet mash at the level of two grams per bird. These workers found no difference in weight between the treated and non-treated lots. The chickens, Rhode Island Red x Light Sussex, were three months of age, however, when the treatment started. Crew (1925) pointed out that during the course of this work that a marked increase was observed in the rate of plumage growth and replacement. Cole and Reid (1924) found that the feeding of desiccated thyroid stimulated the rate of growth of new feathers in adult males. Radi and Warren (1938) found that the injection of thyroxin into the pectoral muscles of each Rhode Island Red chick at the age of three weeks resulted in better feathered birds at seven weeks of age. With respect to body weight, however, the controls and experimental groups were very similar.

Koger, Hurst, and Turner (1942) reported improvement of growth and appetite in mice receiving subcutaneous injections of crystalline thyroxin. Virgin female mice, weighing 13-16 grams, were injected with thyroxin in doses varying from .015 to .04 milligrams daily. The thyroxin-injected animals repeatedly gained an average of 28 percent more weight at five weeks of age than the controls. The difference between the treated and controls was less after five weeks. The food intake, also, was about 25 percent more in the treated over controls. The treated mice stored more nitrogen and gained more in body weight per unit of food intake than the controls. After the rapid gains of the treated animals subsided, the controls were more efficient in storing fat than the thyroxin-injected animals.

Although investigation on iodinated proteins date back more than fifty years, only in the last few years have the effects been consistent. Reineke and Turner (1941) reported that the iodinated proteins prepared in their laboratory consistently produced thyroidal effects when given orally to either normal or thyroidectomized animals. Reineke, Willimson, and Turner (1942) found that iodinated protein differed from thyroid or thyroxin in that no response was produced in tadpoles placed in a solution containing the material in the form of a suspension. Metamorphosis was induced, however, if the iodinated casein was given orally or by injection. Further investigations at the Missouri Agricultural Experiment Station have revealed that guinea pigs, mice, and rats respond similarly when injected either with thyroxin or thyroprotein. These findings greatly facilitated the standardization of the material, since the injected-thyroprotein animals could be compared directly with injected-thyroxin animals.

Parker (1943) fed iodinated casein in the diet at the level of 0.025 to 0.2 per cent to Rhode Island Red chicks until 12 weeks of age. He found the difference in rate of gain to be of doubtful significance, although his data indicated that at the proper level the iodinated casein-fed birds might effect a growth rate above the controls. The differences in rate of feathering were highly significant at the higher levels. Koger, Reineke, and Turner (1943) treated immature virgin female mice with thyroactive iodocasein by both oral and subcutaneous administration. The treated animals gained more in body weight and in total length than the controls. Irwin, Reineke, and Turner (1943) reported that thyroprotein, with a potency of 3.1 per cent that of thyroxin, mixed in a basal mash at the level of 36 grams per 100 pounds of mash produced slightly heavier White Plymouth Rock chickens at 12 weeks of age than the controls. When fed at levels lower than 36 grams per 100 pounds of feed, the treated birds did not produce gains different from the controls. As the level of iodinated casein increased beyond 113 grams per 100 pounds of feed, mortality increased and growth was depressed. These workers concluded that from the standpoint of both growth and feathering the preferred levels of iodinated casein per 100 pounds of feed were 113 and 36 grams, respectively. Later, however, Turner, Irwin, and Reineke (1944) fed thyroprotein to Barred Plymouth Rock cockerels at the level of 45 grams per 100 pounds of feed. The treated birds grew more slowly than did the controls, and it was concluded that the level (0.1 percent of the feed) was the upper limit of tolerance for this breed without depressing the rate of growth.

Wheeler, Hoffman, and Graham (1948) found that thyroprotein at the level of 10 grams per 100 pounds of feed resulted in a significant increase in body weight of Rhode Island Red males at 12 weeks of age. The treatment resulted in a decrease in weight of the testes, adrenals, thyroid, pituitary, and comb weight of the males. Treated birds grew faster than the controls for the first six weeks. At 12 weeks of age, the treated females were not significantly heavier than the controls, although the treated males were significantly heavier than the controls. Furthermore, the weights of the treated males appeared more uniform. Although the controls had more abdominal fat at 12 weeks than the treated, the difference was not significant.

Recent work has indicated that the diet is extremely important in the role of action of the iodinated casein. Robblee, Nichol, Cravens, Elvehjem, and Halpin (1948) found that a thyrotoxic condition in the chick, induced by feeding desiccated thyroid or iodinated casein, was effectively counteracted by supplementing the diet with condensed fish solubles or a concentrated liver extract. Increased growth response was obtained upon the addition of either iodinated casein or desiccated thyroid to a ration containing a sufficient amount of fish solubles. These findings may in part help to explain some of the varying results in use of thyroid-active materials at the different experiment stations.

Much speculation is in the literature of olden days regarding the function of the thyroid gland. According to Schneider (1939), who made a complete historical review of the literature, the older scholars thought that the function of the thyroid was to lubricate the larynx and pharynx. Schiff (1856), probably published the results of the first attempt to study the function of the thyroid by the surgical removal of the gland from dogs. A few of his operated animals lived for a period of time after the operation. Most of them soon died, however, with tetany. In all cases, growth stasis occurred. Work since the time of Schiff has definitely shown that the lethal effects of thyroidectomy observed by him were the result of the removal of the parathyroid glands with the thyroid.

Greenwood and Blyth (1929) removed the thyroids from Brown Leghorn chicks from 32 to 80 days after hatching. The birds were weighed every two weeks until 38 weeks old. The workers observed that the thyroidectomized birds had lower weights than the controls.

Landauer (1929) reported, in a morphological and histological study of a dwarf Rhode Island Red pullet, a condition which he thought was analogous to human myxoedema. He described the bird as having rugged plumage, dry skin and feathers, deformed beak and tongue, puffed eyes, retardation in the bones of the body, and an enlarged thyroid. His report included five other specimens revealing the same type of dwarfism. He concluded that normal function of the thyroid was necessary in the development of the skeleton and plumage of the domestic fowl.

Schwarz (1930), in a study of hypofunction in Plymouth Rocks, observed that thyroidectomy in males and females resulted in a retardation of growth, a diminution in body weight, and distinct changes in the feather structure. From these observations, Schwarz concluded that feather pigmentation and growth were dependent upon metabolic rate. He believed that the hyperfunction of the thyroid caused an increase in the growth of feathers; hypofunction caused retardation in feather development.

Salmon (1936) removed the thyroid gland from the rat on the first, seventh, and fourteenth day after birth. His results indicated that the earlier thyroidectomies had a more marked affect on growth rate than the later ones. Zalesky and Wells (1937), in a study of the effect of thyroidectomy on reproductive organs in males of annual-breeding ground squirrel, found the body weight and testicle weight much lighter in those animals with no detectable thyroid tissue. Payne (1944) found the body, comb, and gonad weights below normal in chicks thyroidectomized when young.

Blivaiss (1947), in a very complete and detailed study of thyroidectomy in the Brown Leghorn, involving 98 completely thyroidectomized and 154 incompletely thyroidectomized roosters, observed increased obesity and decreased feather growth rate in the thyroidectomized birds as compared with the controls. At six months of age, seven thyroidectomized birds had a body weight of 736.6 grams as compared with 1564.8 grams for a group of similar controls. Also, the head furnishings of the thyroidectomized roosters were considerably smaller than normal at all ages observed. Although the incomplete operatives never reached the weight of the controls, they had a higher body weight than the complete operatives. He found the growth curves of the normal and thyroidectomized roosters showed an increasing divergence with increasing age. The percentage ratio of body weights of thyroidectomized to normal decreased from 62.3 percent at one month of age to 47.0 percent at six months. The ratio increased to 55.8 percent at 12 months of age. This ratio change resulted from the continued growth of the thyroidectomized males, whereas, the controls reached their maximum around six months of age.

Since about 1940, several workers have made intensive studies on the effect of various drugs on thyroid activity. The compounds which have been thoroughly studied are derivatives of either aniline or thiourea. These drugs have been found to prevent the formation of thyroxin by the thyroid gland. The thyroid gland becomes enlarged as a result of the compensatory action of the thyrotropic hormone of the anterior pituitary. Mackenzie, Mackenzie, and McCollum (1941) observed thyroid hypertrophy in rats fed sulfaguanidine. Later Mackenzie and Mackenzie (1942) reported that the thyroid hyperplasia produced by feeding sulfaquinidine to rats could be prevented by the administration of thyroxin. Richter and Clisby (1942) and Kennedy (1942) demonstrated that phenylthiourea and allyl thiourea produced hyperplasia. Mackenzie and Mackenzie (1943) reported that the feeding of sulfaguanidine at the level of two or three percent for varying lengths of time to two-week and twelve-week old chickens resulted in no thyroid inhibition. Astwood (1943), in an extensive study of the relative effectiveness of 106 chemical compounds in inhibiting the function of the thyroid gland in young rats, found 2-thiouracil to be the most effective of the thiourea derivatives. The drugs were administered in the food or drinking water for a period of ten days. The degree of hyperplasia, gross and microscopic, provided an estimate of the activity of the drug. Mixner, Reineke, and Turner (1944) found that 0.1 percent thiouracil or thiourea in the diet for 14 days in White Plymouth Rocks resulted in optimal dosage for the production of maximal enlargement of the thyroid. When the chicks were fed thiouracil for 12 days, maximum thyroid enlargement, expressed as thyroid weight in milligrams per 100 grams of body weight, was obtained. The females exhibited a greater thyroid response than did the males. Nine different breeds of chickens were given 0.1 percent thiouracil in the drinking water. Thyroids of the lighter breeds gave a greater response than the thyroids of the heavier breeds.

Kempster and Turner (1945) fed a ration containing 0.2 percent thiouracil for a 16-day period beginning at ten weeks of age. Growth rate was unaffected but market grade improved. When thiouracil was fed for a 36-day period, however, growth rate was depressed. Andrews and Schnetzler (1946) fed thiouracil at various levels in a broiler ration to Barred Plymouth Rocks between the sixth and fourteenth week of age. Growth was retarded. Glazener and Jull (1946 b) found that the feeding of thiouracil at the 0.1 percent and 0.2 percent levels in the mash from the second to the tenth week to Barred Plymouth Rock x New Hampshire chicks resulted in depressed growth rate, retarded feathering, and reduced comb and testes size as compared with the controls. A sex difference was also observed regarding the thyroid enlargement, the females having the greater response. These workers along with many others have observed that thiouracil had an effect on the fowl similar to thyroidectomy.

Dempsey and Astwood (1943) administered thiouracil and thyroxin simultaneously to groups of rats kept at different environmental temperatures. The amount of thyroxin needed to maintain normal thyroid weight at the different environmental temperatures was considered as an estimate of the actual thyroxin output of normal animals for that temperature. Since the gland varied directly with the rate of secretion of the thyrotropic hormone and inversely with the concentration of the circulating thyroid hormone, an index of the degree of thyroid activity was provided by the size of the gland.

Applying the same method, Schultze and Turner (1945) determined the rate of d, l-thyroxin secretion by the thyroid of the White Leghorn and White Plymouth Rock cockerel. The thyroxin secretion rate was higher on a body weight basis for the White Leghorn than for the White Plymouth Rock. The thyroid secretion rate of the White Leghorn was higher when the growth rate of the two breeds was approximately the same. However, when the growth rate of the White Leghorn was lower than that of the White Plymouth Rock, which occurred about the tenth or twelfth week, the thyroxin secretion of the two breeds on an age basis tended to become the same. Growth rate and thyroxin secbetion followed paralled trends up until 12 or 13 weeks of age in the White Plymouth Rock male and up until 7 or 8 weeks in the White Leghorn male.

Reineke and Turner (1945) reported that in the chicken the d, l-thyroxin is about one-half as effective as the l-form of thyroxin. Thyroxin produced by the thyroid gland is in the l-form and is twice as active as the d, l-form.

Mixner and Upp (1947) compared the thyroid activity of hybrid "double cross" chicks of Rhode Island Red and White Leghorn inbred stock with "single crossed" and New Hampshire x Barred Plymouth Rock cross. The chicks were started on thiouracil and d, l-thyroxin injections at one day and continued until the chicks were 14 days of age. The results secured indicated that the hybrid chicks had a higher level of thyroxin secretion than the single inbred crosses or the New Hampshire x Barred Plymouth Rock cross.

MATERIALS AND PROCEDURE

A rapid-growing and a slow-growing strain of both New Hamphires and Barred Plymouth Rocks were used in this study. The strains were chosen on the basis of previous experimentation and knowledge of their performance. One strain each of New Hampshires and Barred Plymouth Rocks had been developed for broiler qualities. The other strain of each breed had been bred primarily for egg production qualities. Eggs were secured from the orginator of these strains. The New Hampshire eggs were hatched in the fall of 1947 and the Barred Plymouth Rock eggs in the spring of 1948 at the University of Maryland. The rapid and slow-growing strains of New Hampshires were designated as strains A and B and the rapid and slow-growing strains of Barred Plymouth Rocks were designated as strains C and D, respectively. The prodedure from hatching time until 12 weeks of age was approximately the same for the two breeds.

At hatching time, the chicks were sexed. The males and females were banded and the number of secondary wing feathers counted on the right wing of the males. The males were divided at random into five lots. The controls were fed University of Maryland Broiler Mash; see Table I. The four other lots were fed University of Maryland Broiler Mash and thyroprotein, which is known as iodinated casein, thyrocasein, iodinated

TABLE I. University of Maryland broiler mash.

Ground yellow corn	400
Ground heavy oats	300
Wheat middlings	300
Wheat bran	250
Soybean oil meal	200
Corn glutten meal	150
Alfalfa leaf meal	100
Fish meal	100
Meat scraps	100
Dried whey or other milk products	50
Riboflavin concentrate	5
Oyster shell or limestone	25
Bone meal or defluorinated rock phosphate	10
Iodized salt	10
Vitamin A and D feeding oil	4
Manganese sulfate	½
Protein : 21 percent	2000½

protein, or commercially as Protamone. The levels of thyroprotein fed to the four lots were 5, 10, 15, and 20 grams per 100 pounds of feed. These levels were determined on the basis of previous work and preliminary studies made at the University of Maryland. The controls consisted in each strain of from 40 to 50 chicks, and the thyroprotein-fed lots consisted of 12 to 15 chicks each, depending on the size of the hatch. The hatchability was very good in all strains except strain D. Sexing was between 80-85 percent accurate.

The five lots of male chicks were placed in electrically heated batteries. Conditions were made as comparable as possible for the two strains in relation to space and position in the battery. They were fed their respective diets ad libitum. Feed consumption was recorded separately for each lot and strain. Feed wastage was kept at a minimum by shields below the feeders. At six weeks of age the birds were transferred to growing batteries. All of the chickens were kept on experiment until 12 weeks of age. No record was kept of water consumption. Individual weekly weighings were made to the nearest gram on a Toledo Scale. Feed consumption was calculated at the time of weighing. All chicks were starved for a short time before weighing in an attempt to have as uniform conditions as possible.

In addition to counting the number of secondaries at hatching time, feather observations were made at ten days, three weeks, eight weeks, and twelve weeks of age. Tail feather observations at ten days were classified into two groups: (1) true tail feathers about one-half inch in length, and (2) no tail feathers. Feathering at three weeks was classified as (1) feathers, approximately one-half inch wide, covering the length of the back, and (2) no back feathers. Body feathering at eight weeks of age was classified into three groups: (1) body fully feathered, (2) back feathered, bare hips and sides, and (3) bare-backs and bare-sides. At 12 weeks of age a record was made of all birds having bare-backs. For illustrations of different feather classifications, see Figures 1, 2, 3, and 4.

At eight weeks of age the length and width of the combs of all cockerels were measured.

The females of each strain were divided into five lots at three-week intervals. The lots for each strain were made as nearly equal as possible on the basis of body weight at the beginning of the three-week period. One lot served as controls and four lots were fed thiouracil at the level of 0.1 percent in the feed. Simultaneously, with the feeding of thiouracil, thyroxin injections were made daily at four different levels. Thiouracil was fed to inhibit the normal secretion of thyroxin. Thyroxin was then added daily at four different levels for a three-week period in an attempt to determine the relative amount of thyroxin naturally secreted by each strain at a given age.

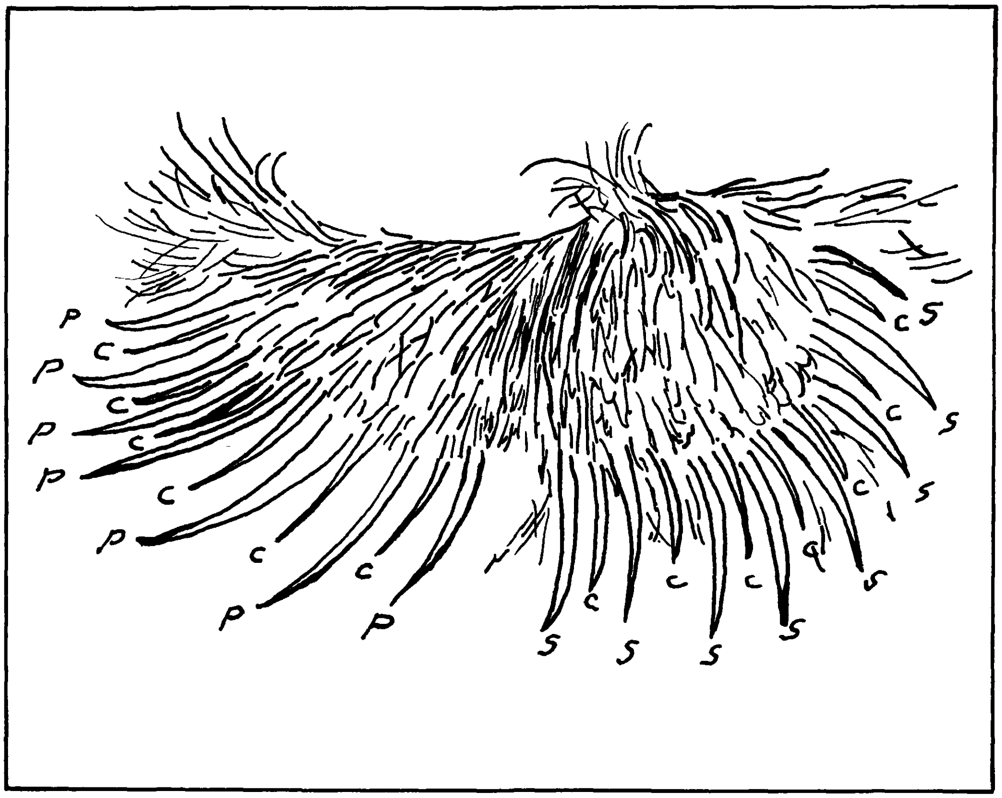

Figure 1. Wing feathering in a day-old chick. The primaries (p), coverts (c) and the secondaries (s) at hatching time. The strains differed in the number of secondaries.

Figure 2. Feathering at ten days. The chick on the left has no tail feathers; the chick on the right has tail feathers.

Figure 3. Feathering at four weeks. The chicken on the left has back feathers covering an area about one-half an inch in width. The chicken on the right has feathers at the base of the tail, but no back feathers.

(a)

(b)

(c)

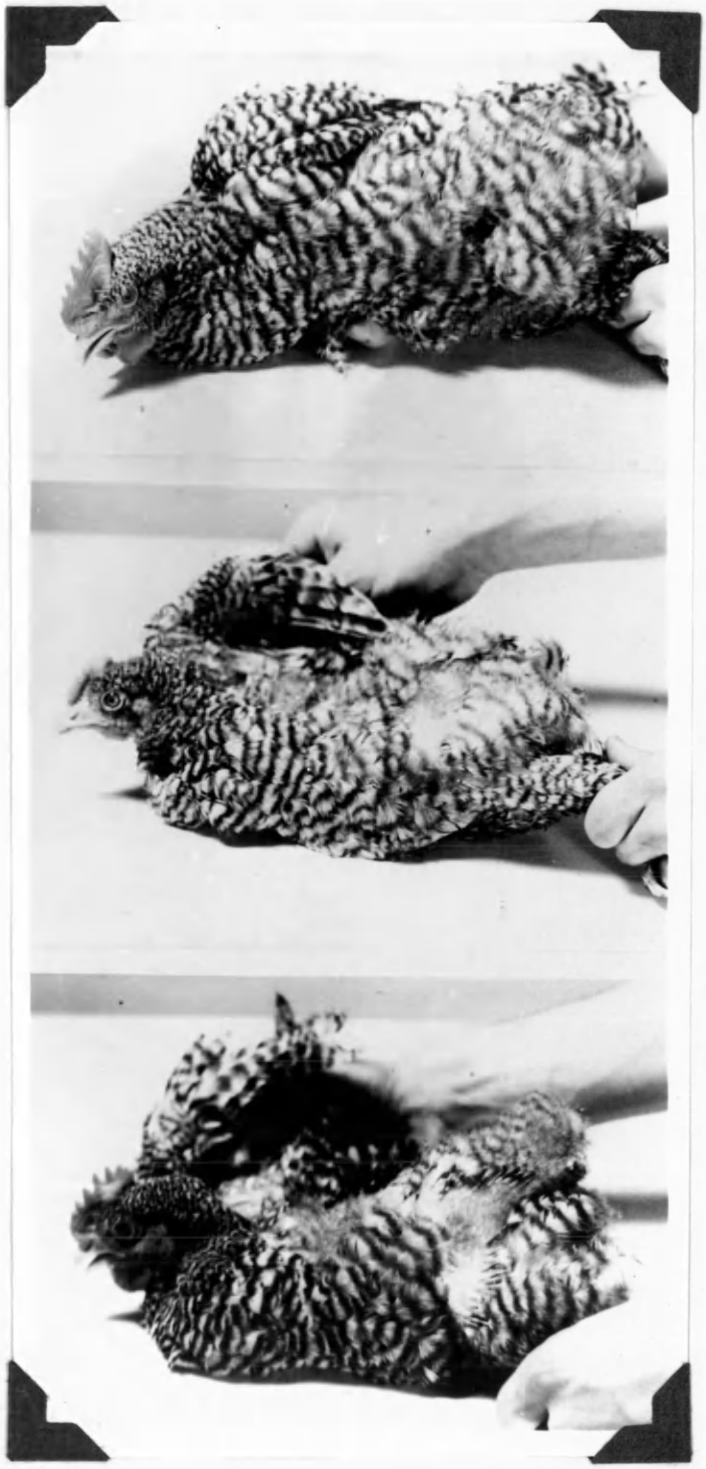

Figure 4. Feathering at eight weeks. (a) cockerel completely feathered, (b) cockerel with back feathered but hips bare, (c) cockerel with both back and hips bare.

Since thiouracil inhibits the formation of thyroxin, the excess stimulation of the thyroid by the anterior pituitary results in hypertrophy of the thyroid gland. The injection of graded doses of thyroxin caused the weights of the thyroids of the thiouracil-fed birds to be reduced, proportionally to the dosage of thyroxin. The amount of thyroxin necessary to prevent hypertrophy in thiouracil-fed birds was an estimate of the relative thyroxin secretion of the bird.

Crystalline thyroxin purchased from Squibb and Company was used in this experiment. The thyroxin was dissolved in alkaline solution such that 0.1 cc of solution contained the daily dosage. All females were killed at the end of the three-week period and the thyroid glands extracted and weighed to the nearest tenth of a milligram. Liver weights were also made on the New Hampshires, but since the results were similar in all lots, this measurement was not made on the Barred Plymouth Rocks.

ANALYSIS OF DATA

Analysis of variance technique was used to determine if the differences in body weights among the four levels of thyroprotein-treated lots of males were significantly different at three, six, nine, or twelve weeks of age. The F and T-tests were used throughout to test for significances among treatments and strains.

Feed efficiency was calculated as a function of live weight. Spillman and Lang (1924) present the idea that the law of diminishing increment expressed with a high degree of accuracy the relationship between live weight and feed consumption in animals. Jull and Titus (1928) modified the Spillman equation and secured a close agreement between observed and expected values in the growth of chickens. Hendricks (1931) rewrote the original Spillman formula into a simple linear regression, solved by the method of the least squares.

Hendricks, Jull, and Titus (1932), Titus, Jull, and Hendricks (1934), Hess, Byerly, and Jull (1941), Glazener and Jull (1946a), Hess and Jull (1948), and McCartney and Jull (1948), have found the principle applicable to feed efficiency studies in poultry. In using the principle of diminishing increment, efficiency was plotted as a function of live weight. The equation used in the investigation was $E = C - kW$.

In the formula, $E = \frac{\text{gain for the period}}{\text{feed consumed for the period}}$,

and $W = \frac{W_1 - W_2}{2}$, in which W_1 was the weight of the chickens at the beginning of the week and W_2 was the weight at the end of the week. "C" and "k" are constants whose values were determined by the use of the least squares method. "C" might be thought of as the theortical maximum efficiency if no feed were used for maintenance and "k" as the maintenance requirement per unit of feed.

Rate of feathering was classified according to the description in the procedure and analyzed on an index basis. When two classifications were used, the top class was scored 100 and the bottom class 50. When three classifications were used, the top class was scored 100, the middle class 67, and the bottom class 33. Comb products for the males were calculated from the length x height of comb at eight weeks of age. Jones and Lamoreux (1943) showed that the product of the length and height of the comb gave higher coefficients of correlation with comb weight than did the measurement of length, height, the sum of the length and height, or the square root of the product of the length and height.

At three week intervals, relative thyroxin secretion rates were computed for the females fed thiouracil on the basis of thyroid weight as a function of the dosage of thyroxin.

RESULTS AND DISCUSSION

The experimental results indicate rather conclusively that differences existed in the strains and in the response of the strain to treatment. In analyzing the data by the analysis of variance technique, differences in body weights of the four thyroprotein fed lots (5, 10, 15, and 20 grams of thyroprotein per 100 pounds of feed) were not significant within any of the strains at three weeks. At six, nine, and twelve weeks of age, however, significant differences in body weights among treatments within a strain were observed in strains B and C. Although in strain A the average body weight appeared more depressed at the higher level of thyroprotein feeding, no significant difference among the four levels of thyroprotein on the basis of body weight was found. In strain D, thyroprotein feeding appeared to stimulate growth somewhat. No significant difference was found among the various levels in this strain.

By further analysis, no significant difference in body weights was found among treatments within any of the strains fed thyroprotein at 5, 10, and 15 gram level at six, nine, and twelve weeks of age. In this investigation and in preliminary work at the University of Maryland, the 20 gram level of thyroprotein in the ration used here seemed to have had a depressing effect. This observation probably explains the reason for the significant difference in body weights among the four levels of thyroprotein-fed birds, as this difference was removed when comparing the lots fed at the 5, 10, and 15 gram level.

Since no significant difference was found among the body weights of the lots fed thyroprotein at the lower levels within a strain, these three lots were combined and compared with the like controls at three, six, nine, and twelve weeks of age. As Table II clearly shows, a strain difference is definitely present as early as the third week. The New Hampshire strains, strains A and B, differed significantly in body weight from the third through the twelfth week, as also did the Barred Plymouth Rock strains, C and D.

Thyroprotein feeding seemed to have a depressing influence on the growth rate of the rapid-growing New Hampshire strain A throughout the 12-week period. As the graph in Figure 5 shows, the thyroprotein-fed birds appeared somewhat better than the controls during the sixth and seventh week of age. This difference, however, was not significant, and from the eighth week until the birds were taken off experiment at twelve weeks of age, the controls appeared better than the treated.

In the New Hampshire strain B, and in the Barred Plymouth Rock strain C, the treated birds were significantly heavier than the controls from six weeks until the end of the experimental period. In strain D, the treated birds appeared somewhat heavier in body weight than the controls, although the differences were small and not significant. The graphs, Figures 5, 6, 7, and 8, show the growth rates of the control and thyroprotein-fed birds for the four strains.

In viewing the results, the question naturally arises, why does strain A appear to be depressed with thyroprotein feeding? Why is the growth rate of strain D, not significantly increased? Probably strain A has more nearly reached its optimum physiological limit as far as thyroid activity is concerned than has strain B. Therefore, the feeding of thyroprotein caused an increase in thyroid activity beyond its optimum level of efficiency, possibly resulting in higher feed requirement for maintenance. On the same basis, strain B does not seem to have reached its peak of performance from the standpoint of thyroid activity. The feeding of thyroprotein, therefore, at the proper dosage level resulted in a significant increase in growth rate over that of the controls. Strain B, however, was not stimulated to the rate of growth of strain A. The average weights of the controls of strain A were 487, 996, and 1463 grams at six, nine, and twelve weeks, respectively; however the average weights of thyroprotein-fed strain B were 439, 812, and 1221 grams at six, nine, and twelve weeks, respectively.

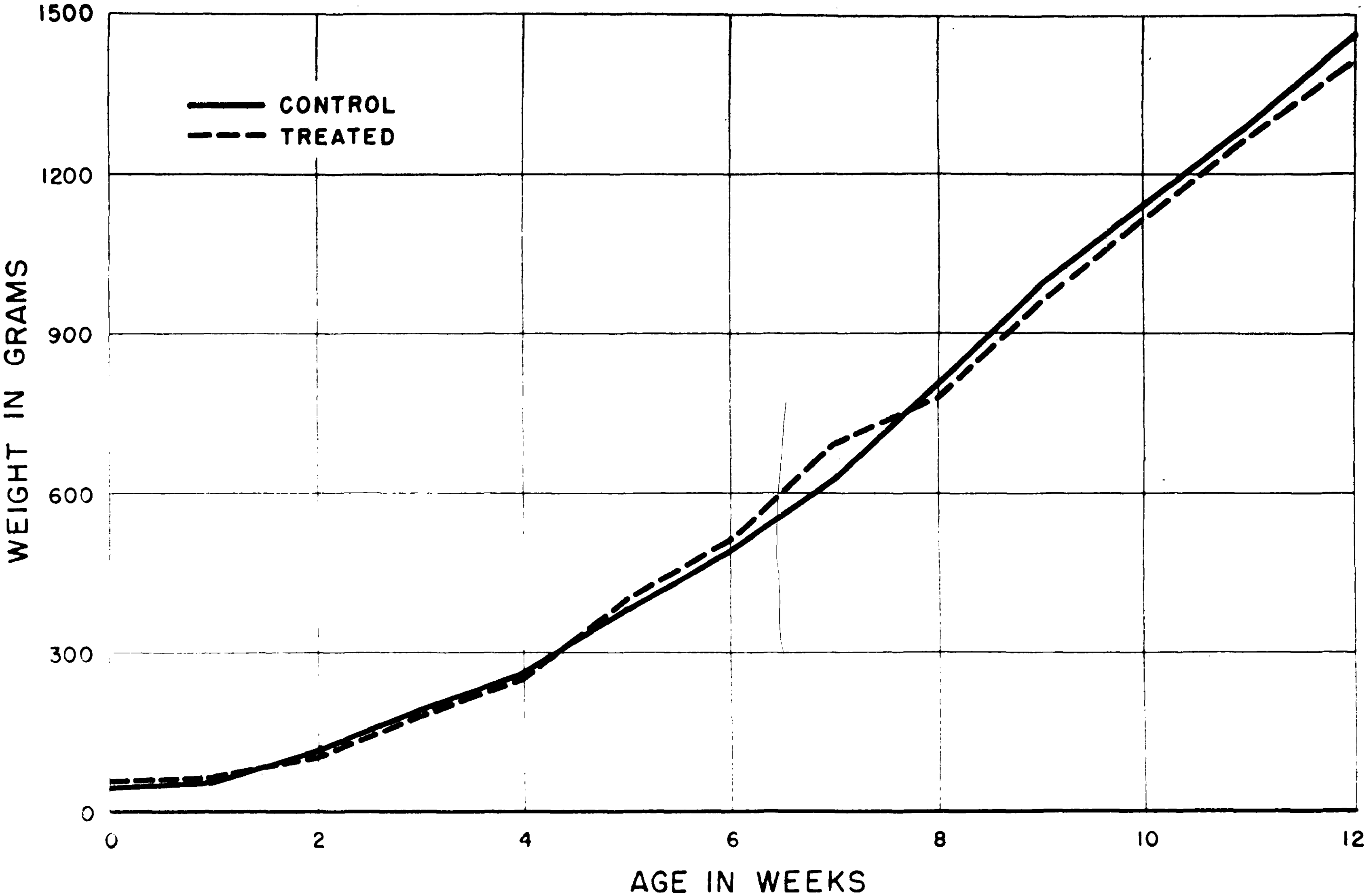

Figure 5. Growth of control and thyroprotein-fed strain A cockerels to 12 weeks.

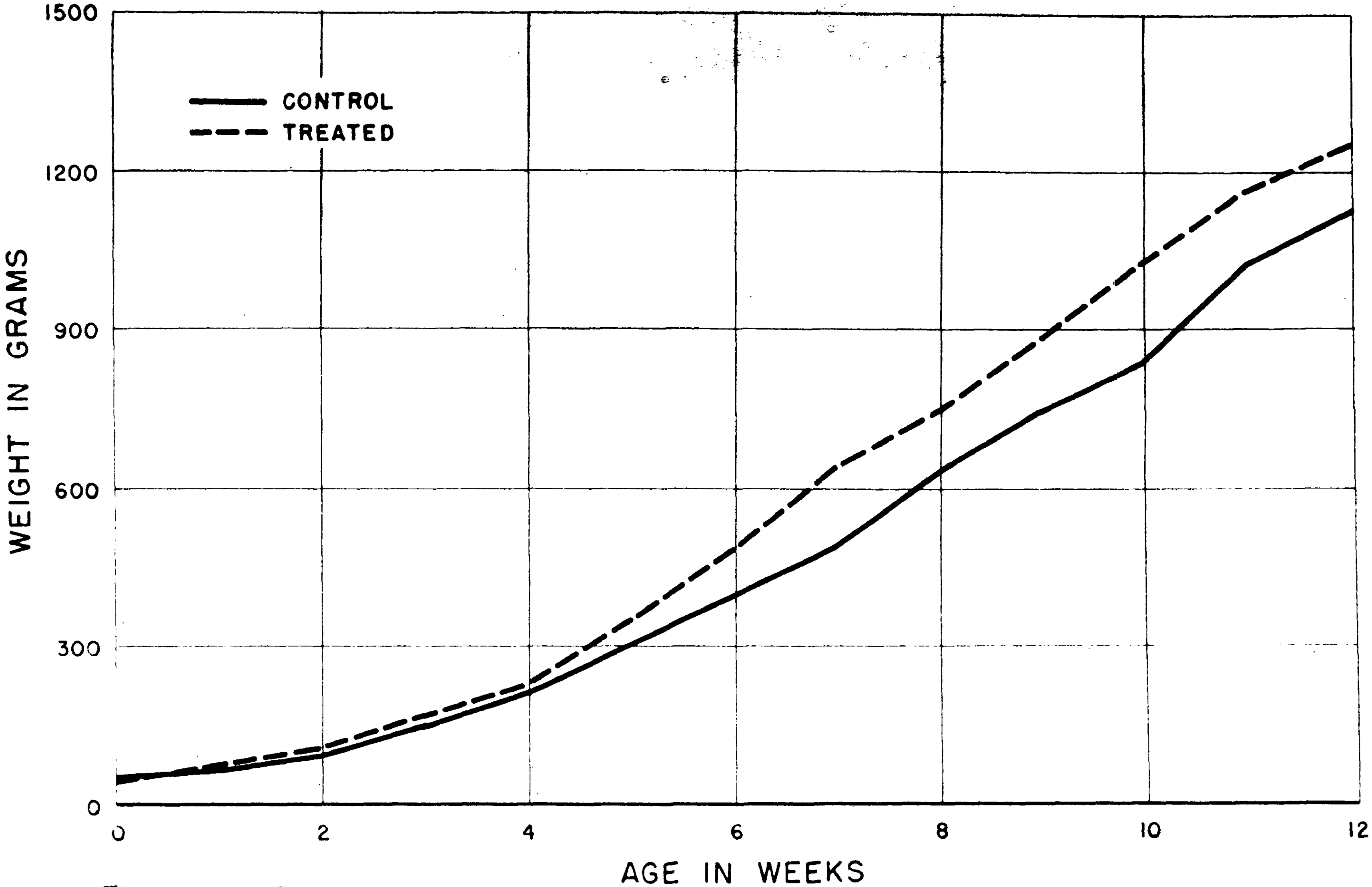

Figure 6. Growth of control and thyroprotein-fed strain B cockerels to 12 weeks.

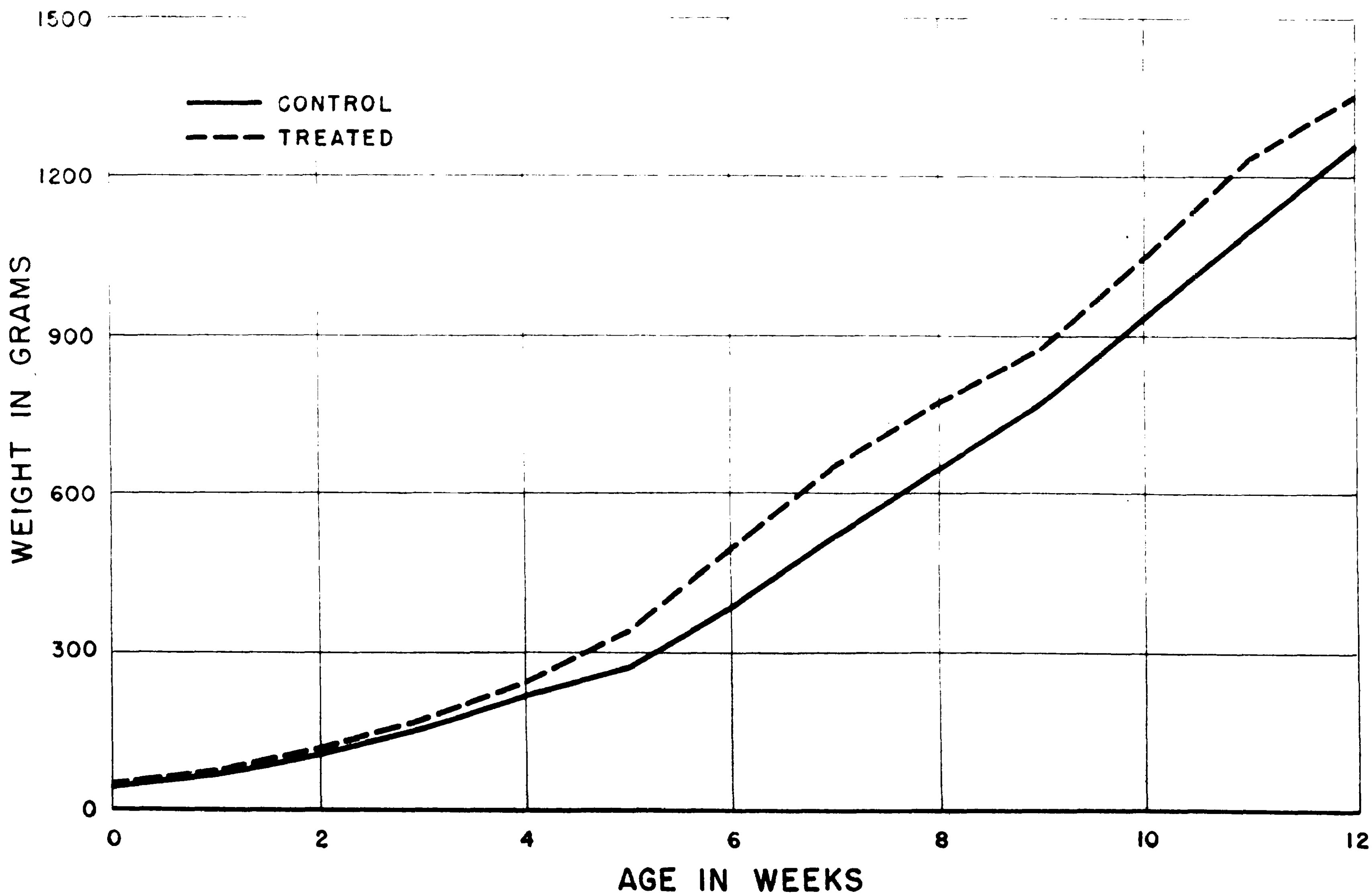

Figure 7. Growth of control and thyroprotein-fed strain C cockerels to 12 weeks.

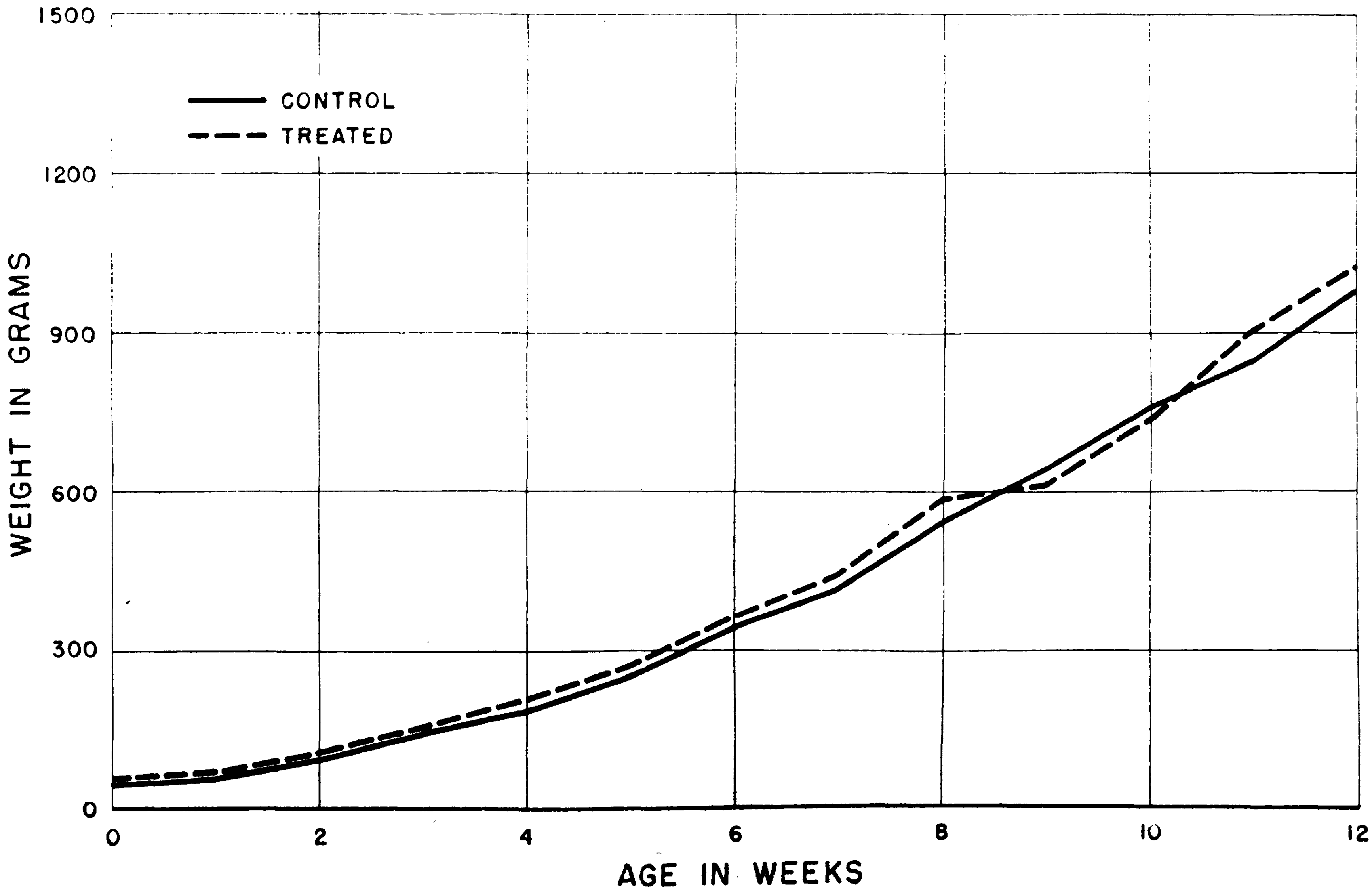

Figure 8. Growth of control and thyroprotein-fed strain D cockerels to 12 weeks.

As Table II shows, both of the strains that were significantly stimulated had very similar rates of growth for the first nine weeks, yet neither of them was stimulated by thyroprotein feeding to equal the controls of strain A. Strain C appeared somewhat better in response than strain B. At twelve weeks of age, strain C thyroprotein-fed males weighed an average of 117 grams more than strain C controls, and at the same age strain B thyroprotein-fed males weighed an average of 88 grams more than strain B controls. Thyroprotein feeding had no significant influence on the growth rate of strain D.

Palmer, Kennedy, Calverley, Lohn, and Weswig (1946) found that anterior pituitary growth harmone promoted growth in their strains of rats, but the amount of stimulation was limited within inherent limits. They found that strains of rats with a lower order of efficiency were affected less definitely toward the attainment of a higher efficiency level than some of the more efficient strains. These workers also reported that periodic administration of desiccated thyroid reduced the efficiency and skeletal length of the male rate of the more efficient strains but did not significantly affect these characteristics in the less efficient strain.

TABLE II. Mean body weights and standard errors for controls and thyroprotein-fed cockerels according to strain and age.

Age Weeks		Strains A	B	C	D
		Body weights in grams			
3	Control	180.5 ± 4.1	147.4 ± 4.3	151.2 ± 4.9	130.4 ± 4.8
	Treated	179.8 ± 3.6	151.1 ± 2.3	161.2 ± 4.6	136.1 ± 3.8
6	Control	487.5 ± 9.9	385.9 ± 11.1	371.3 ± 11.7	331.3 ± 11.4
	Treated	504.7 ± 10.4	438.6 ± 10.8	448.2 ± 12.8	345.2 ± 13.4
9	Control	996.2 ± 29.4	743.2 ± 22.0	779.9 ± 20.8	632.9 ± 25.0
	Treated	951.1 ± 21.1	812.5 ± 20.4	860.2 ± 17.5	649.3 ± 23.1
12	Control	1462.7 ± 33.3	1133.2 ± 29.2	1247.0 ± 29.5	978.5 ± 31.4
	Treated	1392.5 ± 28.6	1221.0 ± 29.7	1354.5 ± 19.3	1033.6 ± 28.5
Number per group:					
	Control	(39)	(36)	(34)	(29)
	Treated	(39)	(34)	(33)	(32)

Although thyroprotein feeding appeared to have a depressing effect on the growth rate of strain A, fewer of the treated birds as compared with the controls weighed below 1200 grams at twelve weeks of age. Likewise, none of the treated weighed much above 1700 grams, whereas some of the controls weighed over 1800 grams at twelve weeks of age; see Figure 9. As compared with the controls, fewer of the thyroprotein-fed birds in the lower classes weighed less than 1000 grams at twelve weeks. Furthermore, none of the controls weighed over 1400 grams. Some of the treated birds, however, weighed more than 1450 grams; see Figure 10.

Strain C gave excellent response to thyroprotein feeding. None of the thyroprotein-fed birds weighed less than 1100 grams at twelve weeks of age. On the other hand, several controls weighed as low as 900 grams at the same age. In the upper classes of body weight, some of the treated birds weighed higher than 1600 grams, whereas the controls did not weigh much higher than 1500 grams. In strain D, little difference was observed in the distribution of weights at twelve weeks of age; see Figures 11 and 12.

Wheeler, Hoffman, and Graham (1948) reported significantly less variability in the thyroprotein-fed Rhode Island Red cockerels than in the controls. Thyroprotein feeding seems to have particularly eliminated some of the poor growth in strains B and C in this study. Perhaps low

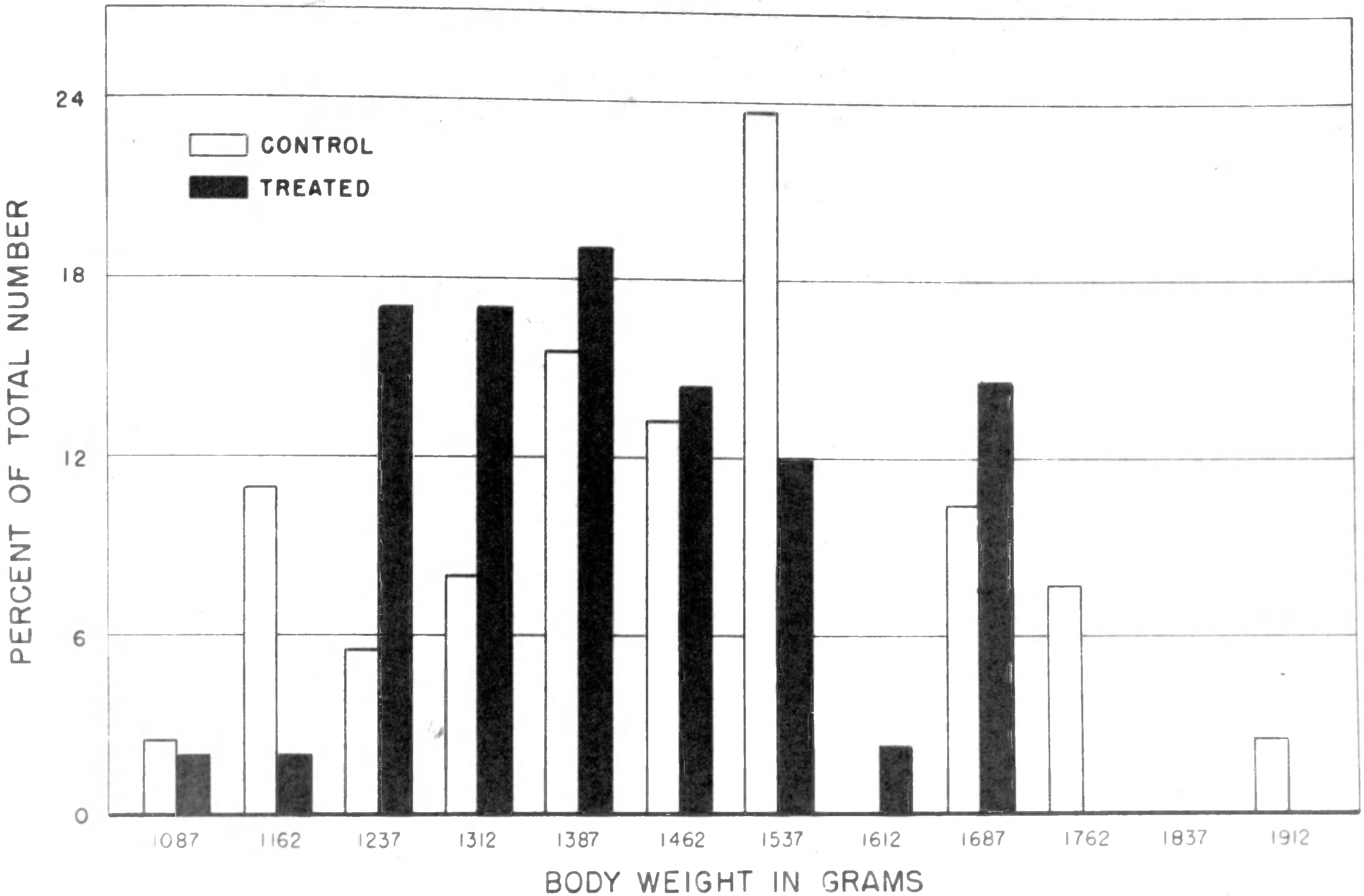

Figure 9. Histogram of body weights of strain A control and thyroprotein-fed males at 12 weeks.

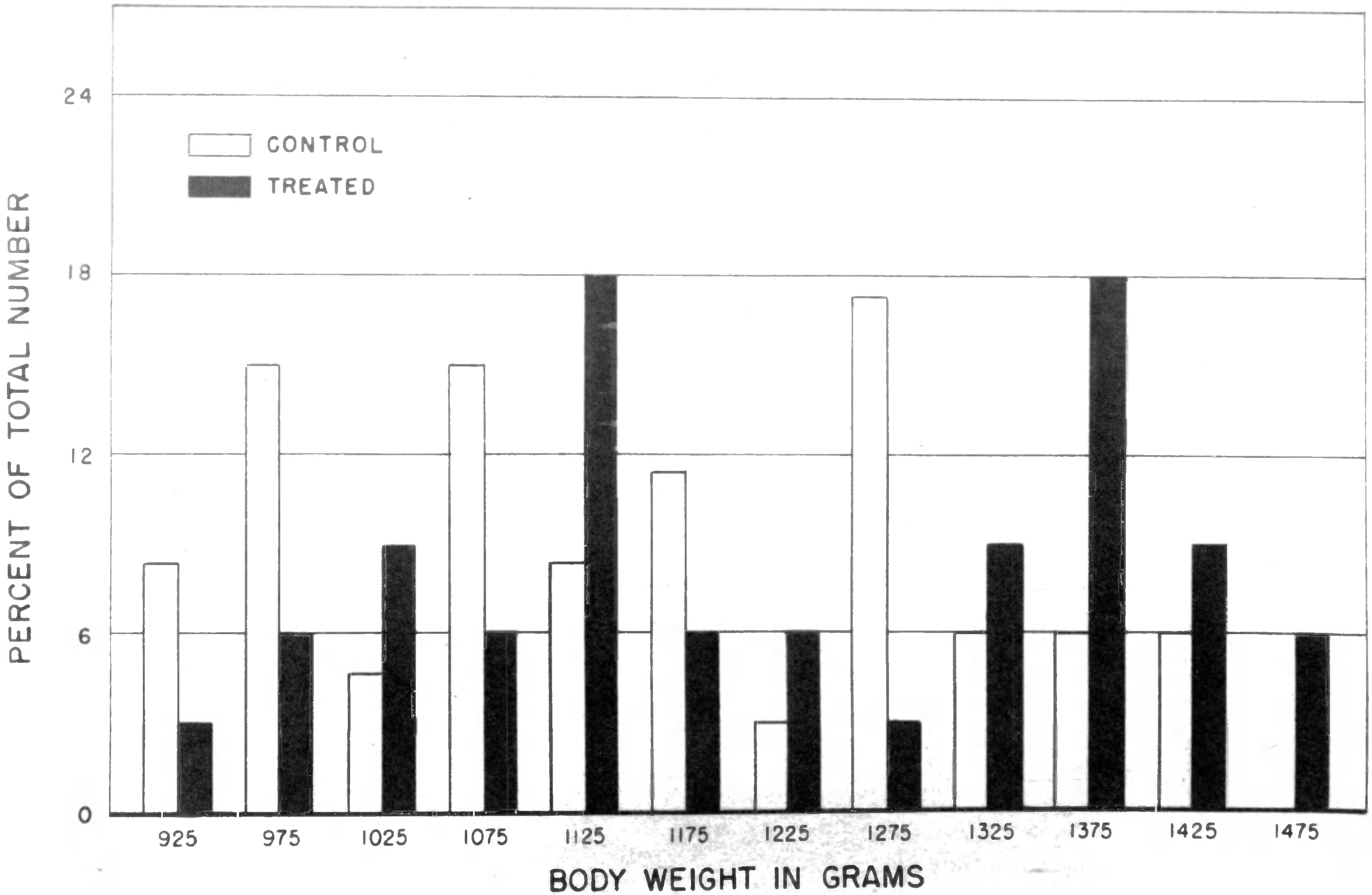

Figure 10. Histogram of body weights of strain B control and thyroprotein-fed males at 12 weeks.

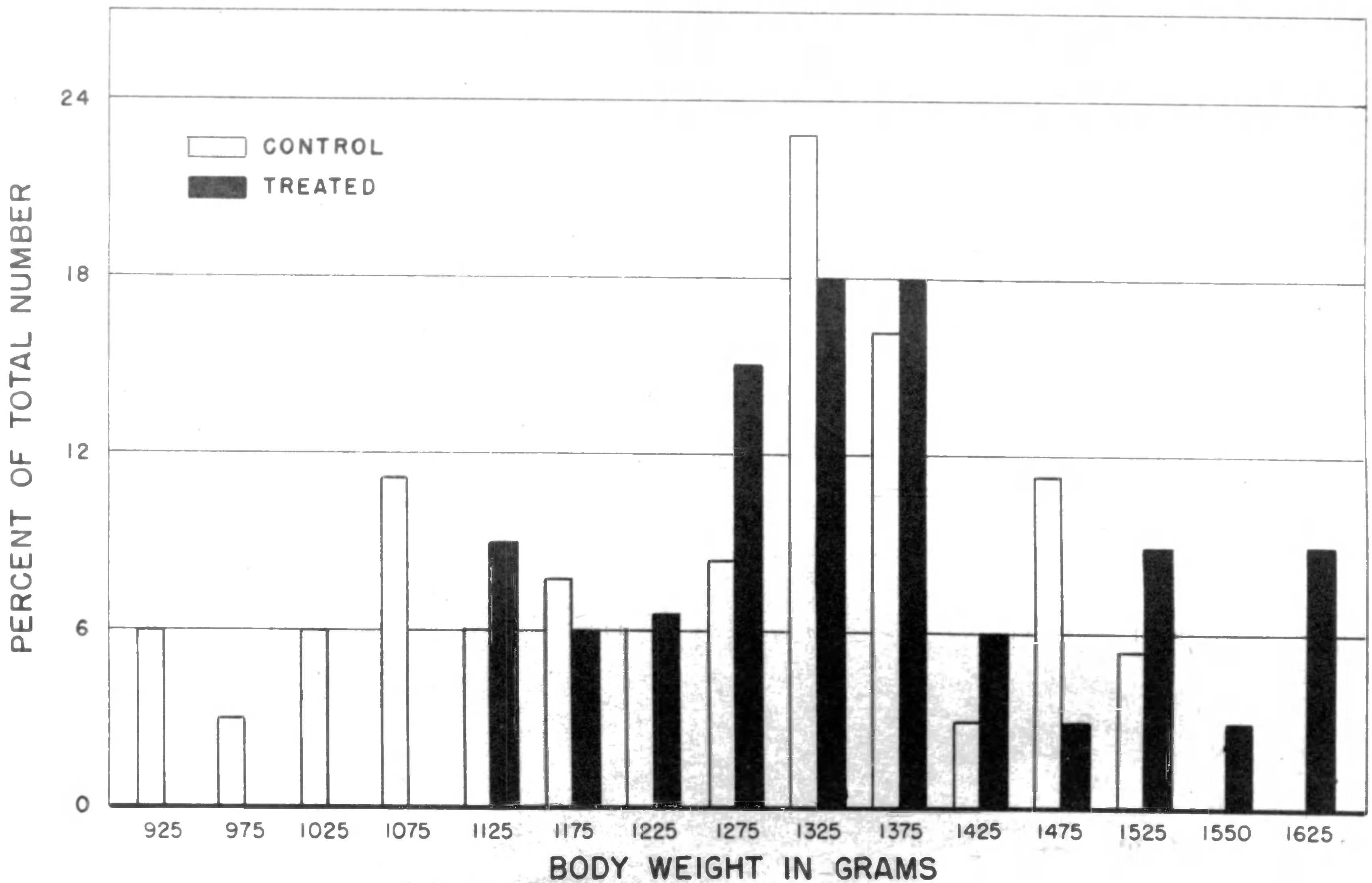

Figure 9. Histogram of body weights of strain C control and thyroprotein-fed males at 12 weeks.

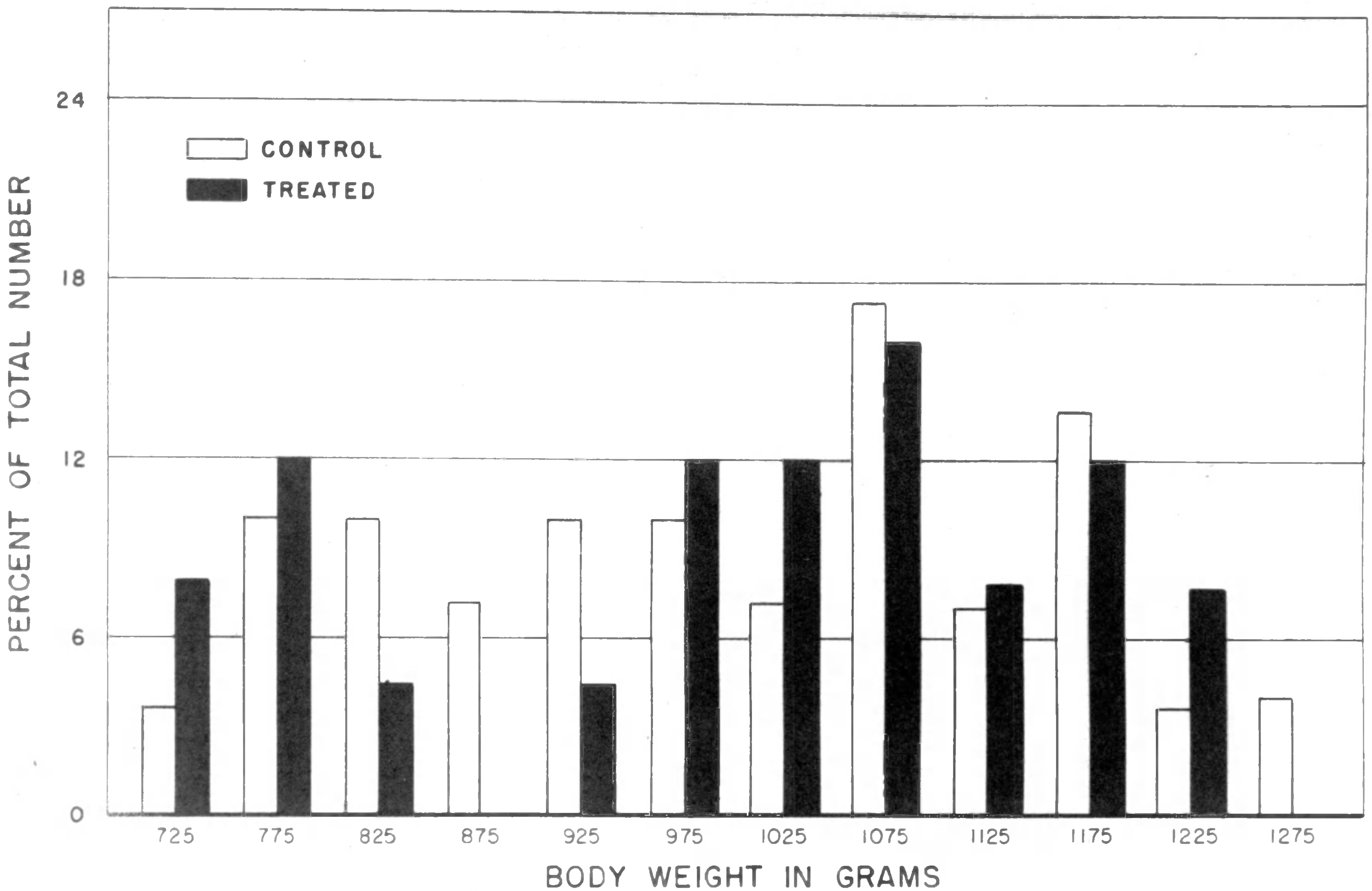

Figure 12. Histogram of body weights of strain D control and thyroprotein-fed males at 12 weeks.

thyroid activity is the cause of some of the runts in growing flocks of chickens. Even in the rapid-growing strain A, the number of birds with the lower body weights was less in the treated group than in the controls. On the other hand, fewer of the treated birds in Strain A were in the upper classes. Although thyroprotein feeding may stimulate growth and reduce variability, the response of a particular strain to treatment should be considered. The genetic-physiological relationship cannot be overlooked.

The poorer strains seemed to have less central tendency of distribution and less homogeneity than the better strains. This observation appeared to be particularly true in comparing strains C and D. Palmer, Kennedy, Calverley, Lohn, and Weswig (1946) reported that in their strains of rats there was somewhat more variation among the low-efficiency strains of males than among the high-efficiency strain males when the energy requirement was determined both on the body weight and on the body surface basis.

Efficiency for the four strains with the respective levels of thyroprotein was calculated as a function of live weight; see Figures 13, 14, 15, and 16. This type of analysis appeared most satisfactory for analyzing efficiency of feed utilization. Comparing weight as a function of feed consumption is not satisfactory as it does not consider the element of time. Winters and McMahon (1933) pointed out that the average efficiency obtained in

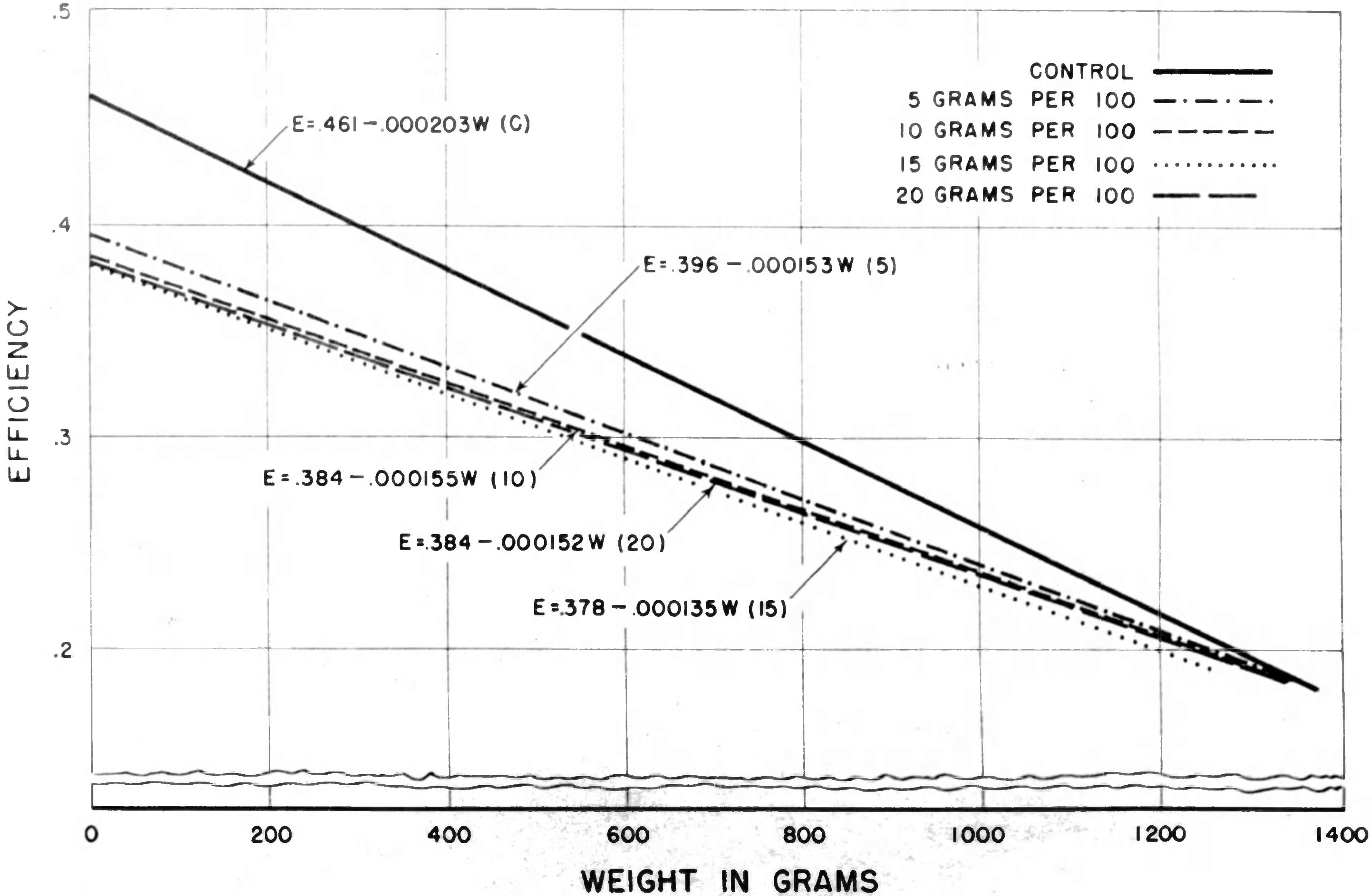

Figure 13. Efficiency of feed utilization as a function of body weight for control and thyro protein-fed lots of strain A males.

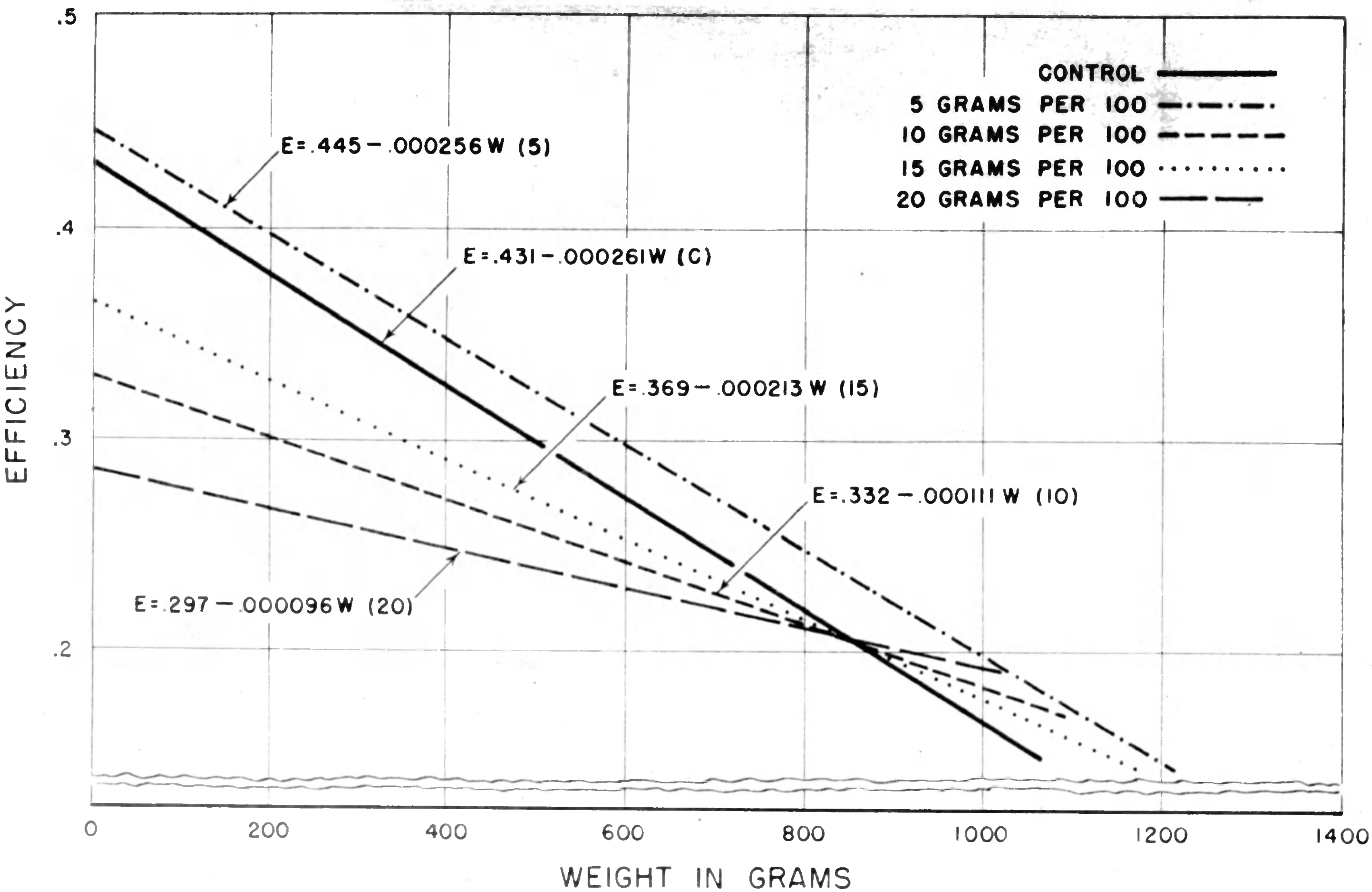

Figure 14. Efficiency of feed utilization as a function of body weight for control and thyroprotein-fed lots of strain B males.

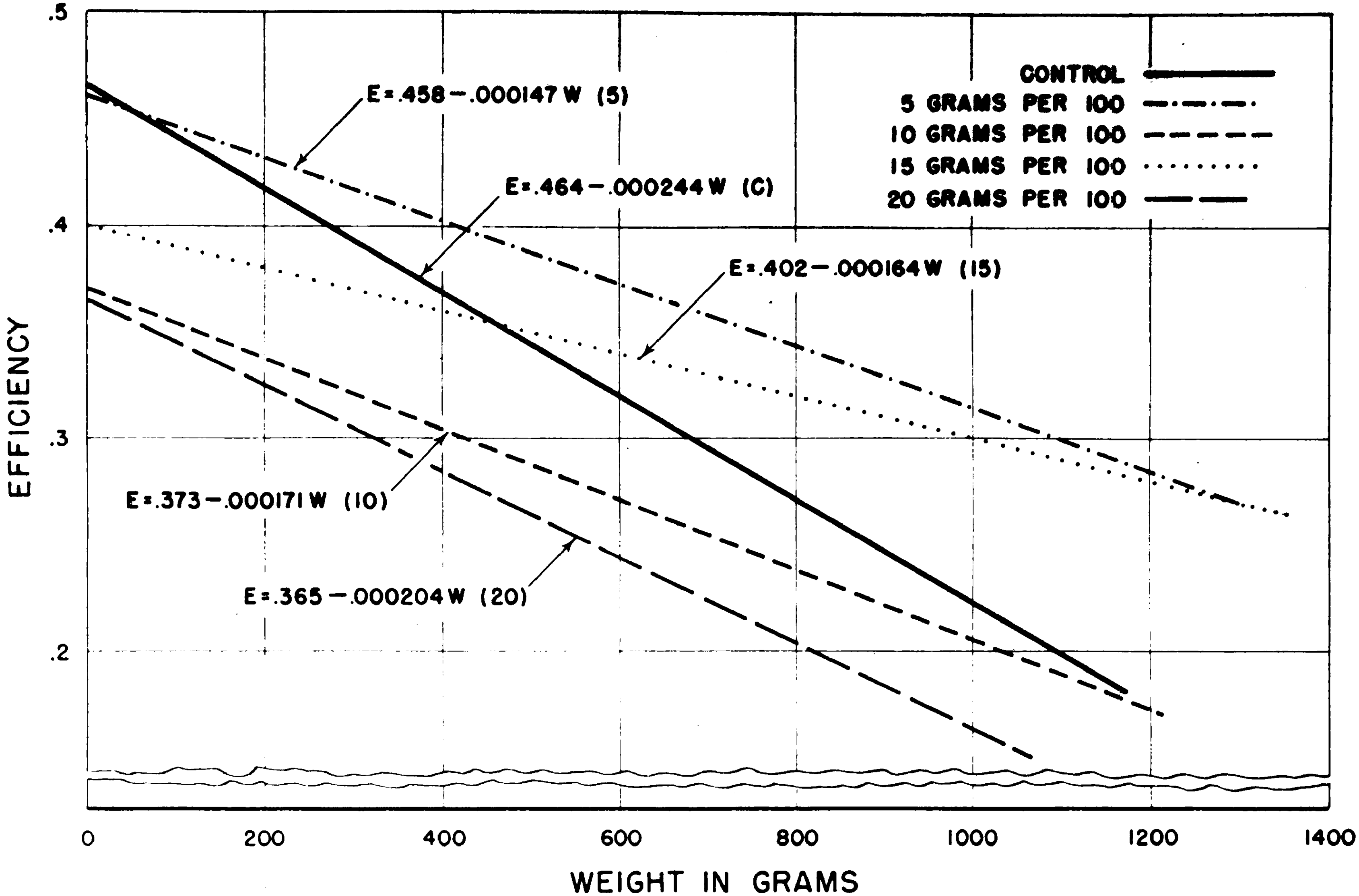

Figure 15. Efficiency of feed utilization as a function of body weight for control and thyroprotein-fed lots of strain C males.

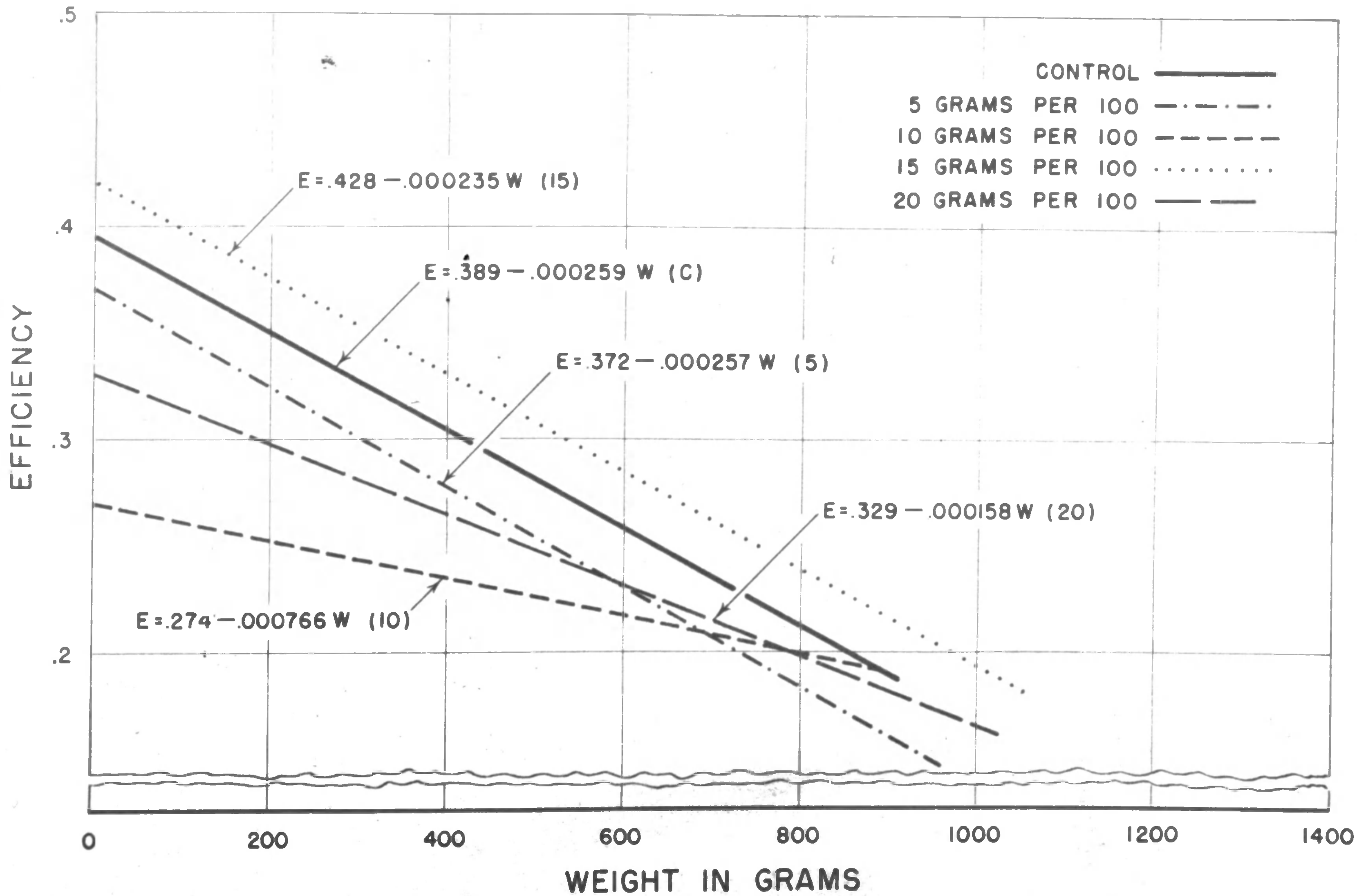

Figure 16. Efficiency of feed utilization as a function of body weight for control and thyroprotein-fed lots of strain D males.

steers by dividing the gain by the total digestible nutrients was probably not a satisfactory method. These workers found that the calf which consumed little feed but continued to grow showed a satisfactory weight increase per unit of feed consumed. Although the equation used, $E = C - kW$, does not consider the element of time, Hess and Jull (1948) found that efficiency values obtained at 500 grams of body weight were almost identical whether the chickens were raised to a definite weight or a definite time. They also found that the agreement was still fairly satisfactory at 1000 grams body weight.

The two strains that were significantly stimulated, strains B and C, seemed to respond well to the 5 gram level of thyroprotein feeding. At 500 grams of body weight, both of these strains were superior in feed utilization to their respective controls. As Table III shows, efficiency at the 500 gram weight dropped as the amount of thyroprotein was increased to the higher levels. Yet, it will be recalled that the average body weights of the birds fed thyroprotein at 5, 10, and 15 gram levels were approximately the same. On the other hand, efficiency at this body weight is apparently somewhat superior at the lowest level of thyroprotein feeding. This amount is a lower level than has been previously recommended for growth. Wheeler, Hoffman, and Graham (1948) reported that they found 10 grams of

TABLE III. Values of constants in the formula E = C - kW. Calculated values for E at 500 grams and 1000 grams according to strain and treatment.

	Level of thyroprotein gm./100 lb.	C	K	E when W=500	E when W=1000
Strain A	0	.468	.000203	.367	.265
	5	.396	.000153	.320	.243
	10	.384	.000155	.307	.229
	15	.378	.000135	.311	.243
	20	.384	.000152	.308	.232
Strain B	0	.431	.000261	.301	.170
	5	.445	.000256	.317	.189
	10	.332	.000111	.277	.221
	15	.369	.000213	.263	.156
	20	.297	.000096	.249	.201
Strain C	0	.464	.000244	.342	.220
	5	.458	.000147	.385	.311
	10	.373	.000171	.288	.202
	15	.402	.000164	.320	.238
	20	.365	.000204	.263	.161
Strain D	0	.389	.000259	.260	.130
	5	.372	.000257	.244	.115
	10	.274	.000076	.236	.198
	15	.428	.000235	.311	.193
	20	.329	.000158	.250	.171

thyroprotein per 100 pounds of feed to be approximately the optimum level. Other workers have suggested higher levels.

In looking at the efficiency values for 1000 grams of body weight in strains B and C, it appears that at the end of the growing period, some of the lots on the higher levels of thyroprotein may have developed a tolerance. Moore (1947) reported that in feeding thyroprotein to cows, the cows dropped in body weight for the first few weeks after feeding, then had a tendency to gain this loss back after a period of time if fed sufficiently.

Since, however, efficiency is a negative function of live weight by formula $E = C - kW$ and since Hess and Jull (1948) reported that agreement of time and weight was not as close at 1000 grams of body weight as at 500, feed utilization was calculated at twelve weeks of age on the basis of gain per unit of feed; see Table IV. Feed efficiency in strains B and C at 12 weeks of age was better in the controls than in the lots fed thyroprotein at the levels of 10, 15, and 20 grams. Although better growth than that in the controls may be obtained by feeding these levels of thyroprotein, probably this increased growth is not economical on the basis of feed consumption. With the diet used in this investigation, probably about 5 grams of thyroprotein per 100 pounds of feed is the optimum dosage. For strains A and D, thyroprotein was apparently of little value. In fact, in strain A the treatment was a definite

TABLE IV. Feed utilization at 12 weeks of age according to strain and treatment.

Strain	Control	Grams of thyroprotein per 100 lb. 5	10	15	20
A	.302	.278	.276	.280	.273
B	.268	.273	.253	.240	.239
C	.288	.318	.264	.279	.261
D	.254	.210	.206	.229	.218

TABLE V. The mean number of secondary wing feathers at hatching time according to strain.

		Mean number and standard error
Strain	A	7.73 ± .080
	B	5.97 ± .016
	C	5.88 ± .098
	D	4.97 ± .011

hindrance to growth. Although the 15 gram level of thyroprotein feeding looked fairly good in strain D, the results were extremely erratic in all lots of this strain. Vander Noot, Reece, and Skelley (1948) reported that the daily feeding of either 0.075 or 0.15 gram of thyroprotein per 100 pounds of live weight had no influence on gains in body weight or the amount of feed consumed per 100 pounds of gain in pigs. On the other hand, the feeding of 0.225 gram did not influence gains in weight, but this level did increase the amount of feed consumed per 100 pounds of gain.

At the time of hatching, the number of secondary wing feathers in the right wing was recorded. Strain A differed significantly from strain B, and strain C differed significantly from strain D; see Table V. Darrow and Warren (1944) and Glazener and Jull (1946c) showed that the number of secondaries at hatching time was a good measure of early feathering.

The chicks placed on thyroprotein and the controls were observed for degree of feathering at ten days, four weeks, eight weeks, and twelve weeks of age. None of the strains except strain A had tail feathers at ten days. Strain B feathered very slowly the first few weeks. Some of the birds were a month old before showing tail feathers one-half inch in length. At twelve weeks of age, all strains were fairly well feathered. Strain A was feathered most completely.

As was previously explained, a feather score was used. When three classifications were used, birds were scored 100, 67, and 33; when two classifications were used, they were scored 100 and 50. See Figures 1, 2, 3, and 4. Table VI gives the average feather indices according to strain and treatment. Thyroprotein feeding appeared to stimulate feathering at four and eight weeks of age in all strains except strain A. The higher levels were most effective in stimulating feathering at these ages. At twelve weeks all lots within a strain had approximately the same degree of feathering.

At eight weeks, the comb areas were calculated in square centimeters for the cockerels of all strains. Jones and Lamoreux (1943) reported that length x height of comb gave a high correlation with comb weight. By analysis of variance, no significant difference was found in comb areas among the four levels of thyroprotein-fed lots within a strain. The different lots were combined and analyzed for comb area approximately the same as for body weight.

The rapid-growing strain of each breed had a much larger comb than that of its respective slow-growing strain. Probably the birds of the rapid-growing strain had a higher gonadal activity. Jaap (1947) reported that the combined weight of the testes of day-old chicks varied from 2.0 to 22.7 milligrams. Large testes size appeared to be an embryonic manifestation of early sexual development and was associated with rapidity of growth rate in the early post-embryonic period.

TABLE VI. Mean feather indices at ten days, four weeks and eight weeks in cockerels according to strain and treatment.

	Level of thyroprotein per 100 lb.	Ten days	Four weeks	Eight weeks
Strain A	0	98	96	82
	5	97	97	78
	10	84	100	77
	15	100	100	78
	20	90	90	74
Strain B	0	--	--	52
	5	--	--	62
	10	--	--	57
	15	--	--	67
	20	--	--	67
Strain C	0	--	66	64
	5	--	82	76
	10	--	83	70
	15	--	79	78
	20	--	85	87
Strain D	0	--	54	50
	5	--	59	50
	10	--	59	53
	15	--	60	60
	20	--	62	67

The comb areas of the treated lots of strains B and C were significantly larger than the comb areas of the controls of these strains; see Table VII. Wheeler, Hoffman, and Graham (1948) reported that thyroprotein-fed Rhode Island Red cockerels had a significantly smaller comb weight than did the controls. These workers, however, recorded comb weights at twelve weeks of age and raised their chickens under environmental conditions different from those in the present experiment.

To further study the relative thyroid activity of the various strains, the technique of feeding thiouracil and simultaneously injecting graded dosage of thyroxin was employed. Dempsey and Astwood (1943) reported that in rats the technique of feeding thiouracil simultaneously with the injecting of thyroxin resulted in hyperthyroidism for the first few days. The rats not only had the thyroxin that was injected, but also that from their own glands, as thiouracil did not stop the natural secretion immediately. To overcome this weakness, in this experiment the first lot of New Hampshire pullets was fed thiouracil for three weeks before starting the injections of thyroxin. This procedure was not found satisfactory, however. Probably a few days of pre-treatment with thiouracil would have been satisfactory, but three weeks was too long. Dempsey and Astwood (1943) reported that with an assay period as long as two weeks, this early error of hyperthyroidism had a tendency to correct

TABLE VII. Mean comb areas for cockerels at eight weeks according to strain and treatment.

Strain	Comb Area (sq. cm.) Controls	Treated
A	10.15±0.6	10.19±0.6
B	3.72±0.2	4.49±0.2
C	10.72±0.7	11.81±0.6
D	3.58±0.3	3.27±0.2

TABLE VIII. Relative daily thyroxin[1] secretion rate for three assay periods in four strains of females.

Strain		Period 3-6 wk. (gamma per bird)		6-9 wk. (gamma per bird)		9-12 wk. (gamma per bird)
A	(25)[2]	----	(25)	23.4	(12)	27.1
B	(25)	----	(25)	18.8	(11)	26.0
C	(25)	18.9	(25)	26.6	(22)	----
D	(21)	13.4	(25)	23.0	(17)	----

[1]Secretion rate calculated on the basis of Crystalline d, l-form, which is only one-half as active as the l-form produced by the gland.

[2]Refers to the number of birds per lot.

itself. Rats that had been allowed a period to exhaust their natural supply of thyroxin did not differ significantly from those simultaneously fed thiouracil and injected with thyroxin for the two-week period. Schultze and Turner (1945) employed a similar method in determining the relative thyroxin secreting rate of White Leghorns and White Plymouth Rocks.

Five comparable lots of approximately five females each were selected from each strain at the beginning of an assay period. One lot served as the control, and four other lots were fed thiouracil and injected thyroxin at four levels. Assays were made over the following three-week periods: 3-6, 6-9, and 9-12 weeks. At the end of the assay period, the sixth, ninth, and twelfth week, the birds were killed and their thyroids extracted and weighed. The weight of the gland in milligrams per 100 grams of body weight was then plotted as a function of the level of thyroxin dosage. The amount of thyroxin necessary to maintain the gland at the size of that of the control was considered the relative amount of thyroxin naturally secreted by the females of that strain. The amount secreted was calculated by means of the least squares method. The 3-6 week period for the two strains of New Hampshires was lost because of the long pre-treatment period with thiouracil, and the 9-12 week period of Barred Plymouth Rocks was lost because three dosage levels given were too high. The dosage levels had to be established for each three-week period by speculation and interpolation from the previous period.

Table VIII shows the relative amount of thyroxin secreted by each strain for the three periods. Since the assays were at different times of the year and were used with different solutions of thyroxin, comparisons should only be made between strains of the same breed.

As Table VIII shows, the rapid-growing strains had a relatively higher daily level of thyroxin secretion than did the slow-growing strains. This result seems logical, as Turner and Schultze (1945) found that growth rate and thyroxin secretion rate followed parallel trends.

Since thyroxin secretion was calculated on the basis of thyroid/body weight ratio to dosage of thyroxin, the question arises: Is the greater body weight of the rapid-growing strains the result of more active thyroids, or is the greater thyroxin production the result of the greater body size of the rapid-growing strains? Which is the cause and which is the effect? To partially answer this question, the average body weight of the slow-growing strain at nine weeks was figured as a percentage of body weight of the rapid-growing strain. Strain B was found to weigh 88 per cent of strain A, and strain D was found to weigh 91 percent of strain C. If the strains were secreting entirely on the basis of body size, strain B should have secreted 88 percent as much thyroxin as did strain A, and strain D 91 percent as much thyroxin as strain C. If this were true, strain B should have secreted 20.7 gamma of thyroxin per day, and strain D should have secreted 24.1 gamma of thyroxin per day. These two strains, however, secreted less than this amount of thyroxin; see Table VIII. These results seem to indicate a higher thyroxin secretion in the females of the rapid-growing strains. At twelve weeks of age the two New Hampshire strains were practically equal. The standard error of the coefficient of regression was determined in the least squares equation, $Y = a - bX$, and the differences in the coefficients were found not to be significant at this age.

Although the thyroid gland probably does not naturally release a single output of thyroxin as was done by the injections, the method employed did give the relative amount of thyroxin required daily, allowing comparison between strains in a breed. This measurement may be an indication of the activity of the anterior pituitary as well as of the thyroid gland.

SUMMARY

A rapid-growing and a slow-growing strain both of New Hampshires and Barred Plymouth Rocks were used in this experiment. The cockerels were fed thyroprotein at the levels of 5, 10, 15, and 20 grams per 100 pounds of feed. Growth rates, feed efficiency, and rate of feathering were measured in all lots of each strain until the birds were twelve weeks of age. Comb measurements were made at eight weeks. Data were analyzed by statistical procedures.

The females of the rapid-growing and slow-growing strains were simultaneously fed thiouracil and injected with various levels of thyroxin for three-week assay periods. The thiouracil was fed to inhibit the normal thyroxin secretion. Thyroxin was then injected daily at four different levels to determine the relative amount naturally secreted by the gland. The females were killed at the end of the assay period and their thyroid glands extracted and weighed. The amount of thyroxin necessary to maintain the gland at its normal size was used as a measure of the relative daily secretion rate.

BIBLIOGRAPHY

Andrews, F. N. and E. E. Schnetzler, 1946. Influence of Thiouracil on Growth and Fattening in Broilers. Poultry Science 25: 124-129.

Asmundson, V. S. and I. Michael Lerner, 1933. Inheritance of Rate of Growth in Domestic Fowl. Poultry Science 12: 250-255.

Astwood, E. B., 1943. The Chemical Nature of Compounds which Inhibit the Function of the Thyroid Gland. Journal of Pharmacology and Experimental Therapeutics. 78: 79-89.

Blivaiss, Ben B., 1947. Interrelations of Thyroid and Gonad in the Development of Plumage and other Sex Characteristics in Brown Leghorn Roosters. Physiological Zoology 20: 67-103.

Crew, F. A. E., 1925. Rejuvenation of the Aged Fowl through Thyroid Medication. Proceedings of the Royal Society of Edinburgh 45: 252-260.

Crew, F. A. E. and J. S. Huxley, 1923. The Relation of Internal Secretion to Reproduction and Growth in the Domestic Fowl. I. The Effect of Thyroid Feeding on Growth Rate, Feathering, and Egg Production. Veterinary Journal 29: 343-348.

Cole, L. J. and D. H. Reid, 1924. The Effect of Feeding Thyroid on the Plumage of Fowl. Journal of Agricultural Research 29: 285-287.

Darrow, M. I. and D. C. Warren, 1944. The Influence of Age on Expression of Genes Controlling Rate of Chick Feathering. Poultry Science 23: 199-212.

Dempsey, E. W. and E. B. Astwood, 1943. Determination of the Rate of Thyroid Harmone Secretion at Various Environmental Temperatures. Endocrinology 32: 509-518.

Dickerson, G. E. and J. W. Gowen, 1947. Hereditary Obesity and Efficient Food Utilization in Mice. Science 105: 496-498.

CONCLUSIONS

1. The rapid-growing strain of New Hampshires was depressed in rate of growth by feeding thyroprotein.

2. The lots of slow-growing New Hampshires and rapid-growing Barred Plymouth Rocks fed thyroprotein at the lower levels were significantly heavier than their controls from the sixth through the twelfth week.

3. Five grams of thyroprotein per 100 pounds of feed was optimum for growth and feed utilization for the ration used.

4. The poorest strain from the standpoint of broiler qualities, Barred Plymouth Rocks, was not significantly stimulated by the feeding of thyroprotein at any of the levels used.

5. Thyroprotein feeding, particularly at the higher levels, stimulated feathering at the ages of four and eight weeks, in the slow-growing New Hampshires, and in the rapid-growing and slow-growing Barred Plymouth Rocks.

6. Neither the slow-growing New Hampshires nor the rapid-growing Barred Plymouth Rocks was stimulated to equal the normal growth rate of the rapid-growing New Hampshires.

7. Inherent limits appeared to control the amount of stimulation possible within a strain.

8. The females of the rapid-growing strains had a higher level of thyroxin secretion than did the slow-growing strains during the growing period.

9. The difference in rate of secretion of thyroxin of the two New Hampshire strains was less at twelve weeks of age than during the earlier growing period.

10. The results indicated that each strain has a physiological optimum level of thyroid activity for growth, feed utilization, and feathering.

Funk, E. M., H. C. Knandel, and E. W. Callenbach, 1930. Statistical Studies of the Variations in the Growth of Single Comb White Leghorns and their Significance. Poultry Science 9: 157-163.

Glazener, E. W. and M. A. Jull, 1946a. Feed Utilization in Growing Chickens in Relation to Shank Length. Poultry Science 25: 355-363.

Glazener, E. W. and M. A. Jull, 1946b. Effects of Thiouracil, Desiccated Thyroid, and Stilbesterol Derivatives on Various Glands, Body Weight, and Dressing Appearance in the Chicken. Poultry Science 25: 236-241.

Glazener, E. W. and M. A. Jull, 1946c. Rate of Feathering and Ten-Week Body Weight Observations in Strains Differing in Shank Length. Poultry Science 25: 433-439.

Goulden, C. H., 1939. "Methods of Statistical Analysis". 277 pp. John Wiley and Sons, Inc., New York.

Greenwood, A. W. and J. S. S. Blyth, 1929. An Experimental Analysis of the Plumage of the Brown Leghorn Fowl. Proceedings of the Royal Society of Edinburgh 48: 313-355.

Hendricks, W. A., 1931. Fitting the Curve of the Diminishing Increment to Feed Consumption Live Weight Curves. Science (N. S.) 74: 290-291.

Hendricks, W. A., M. A. Jull, and H. W. Titus, 1932. The Utilization of Feed by Chickens. Poultry Science 11: 74-77.

Hess, C. W., T. C. Byerly, and M. A. Jull, 1941. The Efficiency of Feed Utilization by Barred Plymouth Rock and Crossbred Broilers. Poultry Science 23: 210-215.

Hess, C. W. and M. A. Jull, 1948. A Study of the Inheritance of Feed Utilization Efficiency in the Growing Domestic Fowl. Poultry Science 27: 24-39.

Irwin, M. R., E. P. Reineke, and C. W. Turner, 1943. Effect of Feeding Thyroactive Iodocasein on Growth, Feathering, and Weights of Glands of Young Chicks. Poultry Science 22; 374-380.

Jaap, R. G., 1947. On the Significance of Variability in Testis Weight of Day-Old Chickens. Abstracts of Papers, 36th Annual Meeting of Poultry Science Association, p. 15.

Jones, D. G. and W. F. Lamoreux, 1943. Estimation of the Size of Comb on Live Fowl. Endocrinology 32: 356-360.

Jull, M. A., 1940. "Poultry Breeding". 484pp. John Wiley and Sons, Inc., New York.

Jull, M. A. and E. W. Glazener, 1946. Rate of Growth in Progeny to Ten Weeks in Relation to Shank Length of Parents. Poultry Science 25: 256-261.

Jull, M. A. and H. W. Titus, 1928. Growth of Chickens in Relation to Feed Consumption. Journal of Agricultural Research 36: 541-550.

Kempster, H. L. and C. W. Turner, 1945. The Effect of Feeding Thiouracil on the Fleshing of New Hampshire Broilers. Poultry Science 24: 94-96.

Kennedy, T. H., 1942. Thio-ureas as Goitrogenic Substances. Nature 150: 233.

Koger, M., V. Hurst, and C. W. Turner, 1942. Relation of Thyroid to Growth. Endocrinology 31: 237-244.

Koger, M., E. P. Reineke, and C. W. Turner, 1943. Influence on Growth of Thyroactive Iodocasein. Proceedings of Society for Experimental Biology and Medicine 52: 236-237.

Koger, M. and C. W. Turner, 1943. The Effects of Mild Hyperthyroidism on Growing Animals of Four Species. Missouri Agricultural Experiment Station Research Bulletin 377.

Landaeur, W., 1929. Thyrogenous Dwarfism (Myxedema Infantilis) in the Domestic Fowl. American Journal of Anatomy 43: 1-43.

MacKenzie, Julia B. and C. G. MacKenzie, 1942. The Effect of "Sulfa" Drugs on the Thyroid Glands in Rats and Mice. Federation Proceedings 1: 122.

MacKenzie, C. G. and J. B. MacKenzie, 1943. The Effect of Sulfonamides and Thioureas on the Thyroid Gland and Basal Metabolism. Endocrinology 32: 185-209.

MacKenzie, Julia B., C. G. MacKenzie, and E. V. McCollum, 1941. The Effect of Sulfanilylguanidine on the Thyroid of the Rat. Science 94: 518-519.

McCartney, M. G. and M. A. Jull, 1948. Efficiency of Feed Utilization in New Hampshires to Ten Weeks. Poultry Science 27: 17-23.

Mixner, J. P., E. P. Reineke, and C. W. Turner, 1944. Effect of Thiouracil and Thiourea on the Thyroid Gland of the Chick. Endocrinology 34: 168-174.

Mixner, J. P. and C. W. Upp, 1947. Increased Rate of Thyroxine Secretion by Hybrid Chicks as a Factor in Heterosis. Poultry Science 26: 389-395.

Moore, L. A. and J. F. Sykes, 1947. Thyroprotein for Cows. Yearbook of Agriculture 1943-47: 107-112.

Morris, H. P., L. S. Palmer, and Cornelia Kennedy, 1933. Fundamental Food Requirements for the Growth of the Rat. VII. An Experimental Study of Inheritance as a Factor Influencing Food Utilization of the Rat. University of Minnesota Agricultural Experiment Station Technical Bulletin 92.

Palmer, L. S., C. Kennedy, C. E. Calverley, C. Lohn, and P. H. Weswig, 1946. Genetic Differences in the Biochemistry and Physiology Influencing Food Utilization for Growth in Rats. University of Minnesota Agricultural Experiment Station Technical Bulletin 176.

Parker, J. E., 1943. Influence of Thyroactive Iodocasein on Growth of Chicks. Proceedings of the Society for Experimental Biology and Medicine 52: 234-236.

Payne, F., 1944. Anterior Pituitary-Thyroid Relationships in the Fowl. Anatomical Record 88: 337-350.

Radi, M. H. and D. C. Warren, 1938. Studies on the Physiology and Inheritance of Feathering in the Growing Chick. Journal of Agricultural Research 56: 679-704.

Reineke, E. P., 1946. Thyroactive Iodinated Proteins. Vitamins and Harmones IV: 207-249.

Reineke, E. P. and C. W. Turner, 1941. Growth Response of Thyroidectomized Goats to Artificially Formed Thyroprotein. Endocrinology 29: 667-673.

Reineke, E. P., M. B. Williamson, and C. W. Turner, 1942. The Effect of Progressive Iodination on the Thyroidal Activity of Iodinated Casein. Journal of Biological Chemistry 143: 285-293.

Reineke, E. P. and C. W. Turner, 1945. The Relative Thyroidal Potency of l- and d, l-thyroxine. Endocrinology 36: 200-206.

Richter, C. P. and K. H. Clisby, 1942. Toxic Effect of the Bitter-Tasting Phenylithiocarbamide. Archives of Pathology 33: 46-57.

Robblee, A. R., C. A. Nichol, W. W. Cravens, C. A. Elvehjem, and J. B. Halpin, 1948. Relation Between Induced Hyperthyroidism and an Unidentified Chick Growth Factor, Proceedings of the Society for Experimental Biology Medicine 67: 400-404.

Salmon, T. N., 1936. Effect of Thyro-Parathyroidectomy in New Born Rats. Proceedings Society for Experimental Biology and Medicine 35: 489-491.

Schiff, M., 1856. Untersuchungen uber die Zuckerbildung in der Leber. Wurzburg. (Schneider, 1939).

Schneider, B. A., 1939. Effects of Feeding Thyroid Substance. The Quarterly Review of Biology 14: 289-310.

Schnetzler, E. E., 1936. Inheritance of Rate of Growth in Barred Plymouth Rocks. Poultry Science 15: 369-376.

Schultze, A. B. and C. W. Turner, 1945. The Determination of the Rate of Thyroxine Secretion by Certain Domestic Animals. University of Missouri Agricultural Experiment Station Research Bulletin 392.

Schwarz, E., 1930. Pigmentierung, Form und Wachstum der Federn des Haushuhns in Abhangigkeit von der Thyreoidenfunktion. Roux' Arch. f. Entwicklungsmech., Bd. 123: 1-38. (Schneider, 1939)

Snedecor, G. W., 1946. "Statistical Methods". 485 pp. The Iowa State College Press, Ames, Iowa.

Spillman, W. J. and E. Lang, 1924. The Law of Diminishing Returns. 176 pp. World Book Company, Chicago.

Titus, H. W., M. A. Jull, and W. A. Hendricks, 1934. Growth of Chickens as a Function of Feed Consumption. Journal of Agricultural Research 48: 817-835.

Turner, C. D., 1948. "General Endocrinology". 604 pp. W. B. Saunders Co., Philadelphia.

Turner, C. W., M. R. Irwin, and E. P. Reineke, 1944. Effect of Feeding Thyroactive Indocasein to Barred Plymouth Rock Cockerels. Poultry Science 23: 242-246.

Vander Noot, G. W., R. P. Reece, and W. C. Skelley, 1948. Effects of Thyroprotein and of Thiouracil Alone and in Sequence in the Ration of Swine. Journal of Animal Science 7: 84-91.

Wheeler, R. S., E. Hoffman, and C. L. Graham, 1948. The Value of Thyroprotein in Starting, Growing, and Laying Rations. I. Growth, Feathering, and Feed Consumption of Rhode Island Red Broilers. Poultry Science 27: 103-111.

Winters, L. M. and H. McMahon, 1933. Efficiency Variations in Steers. Minnesota Agricultural Experiment Station Bulletin 94.

Zalesky, M. and L. J. Wells, 1937. Experimental Studies of the Thyroid. I. Effects of Thyroidectomy on Reproductive Organs in Males of an Annual-Breeding Ground Squirrel. Anatomical Record 69: 79-97.