AMOUNT OF BREAST MEAT AND GRADE OF CARCASS IN RELATION TO BODY MEASUREMENTS IN PUREBRED CORNISH, NEW HAMPSHIRES, BARRED PLYMOUTH ROCKS, AND THEIR CROSSES

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INTRODUCTION

Although chickens have been raised as a source of food by man for many years, comparatively little scientific effort has been made to develop strains of chickens possessing uniform body type combined with superior fleshing ability with a view toward the greatest possible utilization of feed in producing the kind of dressed birds most desired by consumers.

This is due perhaps to the fact that two-thirds or more of the income from raising chickens has come from the production and sale of eggs. Also, the habit of eating the meat of other animals has become strongly established. New information and knowledge concerning poultry genetics, physiology, nutrition and management, increased purchasing power, a growing demand for more poultry meat and a trend toward greater specialization, however, have focused greater attention in recent years upon the development of a more desirable meat-type chicken.

The Brahma, Cochin, Langshan, Jersey Giant, and the Cornish are some of the older and more important breeds of chickens that have been produced primarily for meat purposes. The total number of chickens of these breeds raised, however, is small because each breed mentioned possesses one or more undesirable characteristics, such as low hatchability, slow feathering, late maturity, poor fecundity, inefficient feed utilization, poor body conformation or a small proportion of edible meat which tend either to restrict production by the producer or acceptance by the consumer. A far greater number of chickens of either the New Hampshire, Rhode Island Red, Plymouth Rock, or the Leghorn breeds, in which these undesirable characteristics are less pronounced, are raised and eaten in this country each year.

Even though purebred New Hampshires, Rhode Island Reds, Plymouth Rocks, and Leghorns are the most popular breeds of chickens raised on farms and in commercial egg-producing sections of the United States, millions of young crossbred chickens are raised for market in the large broiler-producing areas each year. Both sexes of these crossbreds are killed and marketed at an early age, 12 to 14 weeks, when the most profitable gains in weight have been made and while the carcass is still soft-meated and tender. Most of the males and some of the female chickens raised in the commercial areas and to a less extent, those raised in the farm flock areas, are likewise disposed of at an early age. All healthy mature chickens raised for egg or meat production are likewise killed to provide food for man at one time or another.

The market grade and value of each of these young and old birds depend primarily upon the body conformation and the amount of flesh present. In the grading and marketing of live and dressed carcasses, plumpness of fleshing throughout the body is essential to high quality. Fullness of muscular development is also basic to maximum fat production. Nevertheless, the type of body found in many individual birds apparently is not conducive to the development of plump breasts. The length of the body in relation to its depth and breadth may be out of proportion, thus presenting a slab-sided carcass, or, at least, an angular type of body. The most desirable carcass for meat purposes appears to be one that is comparatively long and broad, moderately deep, well-fleshed, fat, and with legs that are relatively short, plump, and meaty. Most consumers prefer and are willing to pay more for the white meat than for the dark meat in cut-up chicken. The length, width, depth, and quantity of flesh on the breast is therefore of greatest interest to both seller and buyer. The contour of this area probably has more influence on the grade and value of the bird than any other region.

Two kinds of measurements are used to determine carcass quality in market birds. One kind includes linear and body dimensional measurements, such as weight, length, width, and depth of body, all of which may be determined fairly accurately. The second kind includes commercial grades which are more or less subjective in nature and are determined by the grader according to a set of specifications and from impressions received through the hands and eyes.

PURPOSE OF STUDY

No practical methods of precise measurements on living birds which describe the degree of excellense of the dressed carcass are as yet available. Several methods have been proposed, but none of them have proved to be accurate or simple enough for practical application.

The purpose of this study is to determine the relationship between various body measurements and the amount of breast meat and the grade of carcass in young purebred and crossbred chickens marketed for meat purposes. Information of this kind should be enlightening to breeders and research workers who are endeavoring to develop a more desirable meat-type chicken, to producers who are looking for a better measurement or index of fleshing and fattening, to graders and marketing officials whose judgment is questioned occasionally, and to consumers who are eager to buy meat-type chickens with better appearance and carcass quality.

REVIEW OF LITERATURE

Several investigators have reported on physical measurements as a basis of establishing desirable market conformation in poultry. Most of the investigations appearing in the literature have been made either with mature turkeys or chickens of breeds other than those used in this study.

Rate of Growth

The period of growth in man and animals according to Brody (1927) can be divided into two fairly distinct phases: (1) A self-accelerating phase, during which time rate of growth increases with the increase in size of the organism, and (2) a self-inhibiting phase, during which the time rate of growth decreases with the increase in size of the organism.

The age curve of growth has an increasing slope when plotted during the self-accelerating phase of growth and a decreasing slope during the self-inhibiting phase of growth. The junction between the two phases of growth coincides roughly with puberty in animals and with flowering in plants. Puberty is thus a critical period in the life of the organism not only because it is the beginning of the reproductive period, but also because it makes the transition from a consistently increasing to a consistently decreasing velocity of growth. In the growth curve of man, the major inflection, i.e. the junction between the self-accelerating and the self-inhibiting phases of growth, occurs when the body weight is roughly two-thirds of the mature weight. In domestic animals, it occurs when the body weight is roughly one-third of the mature weight.

These characteristics of growth rate have been observed in poultry. Extensive studies on breed differences in pullets by Kempster (1941) indicate that the junction between the two phases of growth referred to occurs in chickens at about 12 weeks of age, that about one-third of the mature weight of different breeds of chickens has been attained at this age, and that some breeds of chickens grow at a much faster rate than others.

Asmundson and Lerner (1933) observed that the early growth of Plymouth Rocks exceeded that of Leghorns. Jaap and Morris (1937) found that White Leghorns weighed slightly more than Barred Plymouth Rocks at eight weeks of age. They concluded also that growth to eight weeks of age is a separate entity not necessarily associated with mature body weight.

Waters (1937) reached the same conclusion but Schnetzler (1936) concluded that differences in rate of growth are associated with differences in mature weight. Lerner and Asmundson (1938) demonstrated that differences in early growth within the same breed do not always mean corresponding differences in mature weight. Two strains of Single Comb White Leghorns were found to weigh the same at 36 weeks of age, yet at 12 weeks they differed by as much as one-quarter of a pound or 20 per cent.

That differences exist among the rates of growth of certain breeds has been demonstrated by Card and Kirkpatrick (1918), Warren (1930), Waters (1931), Lerner and Asmundson (1932), and others. For instance, it has been demonstrated that Light Brahmas, Barred and White Plymouth Rocks, Rhode Island Reds, and Light Sussex grow faster during the first few weeks than Leghorns and Anconas.

Milby and Henderson (1937) found that chickens, turkeys, and pheasants grow at practically the same rate during periods of constant growth, but that the growth period was more prolonged for turkeys. Pheasants and chickens grow at the same rate for 19 weeks, but while growth of pheasants stopped at that time, the chickens continued growing to 10 months of age. Migratory dudks and geese had very similar growth rates, and the growth rate for both doubled that for turkeys, but the decline occurmed earlier and was much more pronounced.

The growth of the organism as a whole is the sum total of the growth of its parts. Bone, flesh, and fat are the three most important constituent parts of a chicken. According to Jaap (1940) the percentage of bone increases much more rapidly than the percentage of flesh and fat during the early growing period. When the chicken is hatched, it is plump, but during the first few weeks of growth, it develops more bone than flesh or fat. Later in the growth period the percentage of flesh increases more rapidly. Finally, toward the end of the growth period, the percentage of fat increases most rapidly.

Brody (1927) states that the course of growth in length tends to be linear whereas growth in weight is exponential. Huxley (1932) contends that differential growth of a limb or appendage or a well-marked region of the body appears never to be brought about by an equal distribution of excess growth-potential of the organ or region. On the contrary, the growth potential of the organ or region is distributed in the form of a growth-gradient, normally with a simple high point or growth-centre, from which growth-intensity grades downwards in both directions, or in one if the growth-centre is terminal. In general, the less the difference between the growth-coefficient of the organ or region and that of the rest of the body, the less marked and flatter is the gradient, so that in isogonic organs there is scarcely any gradient, but all the parts grow at approximately the same rate as the body as a whole. There are, however, some unusual gradients in which the growth-coefficient or part of the organ to the whole are equal to, above, or below unity.

The terms "heterogony" by Pésard (1918) and "heterauxesis" by Needam and Lerner (1940) are used to describe the growth rate of a part in relation to that of the whole or to other parts, and the term "allometry" refers to growth relationships between groups or individuals compared at maturity or at any other given stage of development. The terms "isauxesis", "tachyauxesis", and "bradyauxesis" respectively are also used by Needam and Lerner (1940) to indicate that the growth rate of the part is either equal to, greater than, or less than that of the whole.

Jaap and Penquite (1938) working with chickens found that skeletal growth ceases earlier than does the body as a whole. During the first two or three months shank length exhibits more rapid growth, tachyauxesis. Therefore, the shank becomes proportionally longer as the size of the body increases. The age at which shank length ceases to become proportionally longer in comparison to body size has been estimated to be about 12 weeks in females and 16 weeks in males. It is suggested that relative growth constants for shank length of female chickens may apply only prior to 12 weeks of age. Evidence that 16 weeks may be a comparable age in males is presented.

In the case of both male turkeys and chickens, growth in length of shank ceases by the end of the sixth month after hatching. Body growth, however, when measured by weight increase, continues to the end of the tenth month. The growth of the shank in the female turkey reaches maturity at least one month earlier than that of the male.

Latimer (1927) found that the rate of the growth of the leg bones in the fowl is higher than the rate of body-weight growth and that the male bones increase from hatching time to maturity to a greater extent than do female bones, with the exception of the femur in which case no difference in rate of growth was observed. Evidence showing that males grow faster then females has been submitted by Jull (1923), Ackerson and Mussehl (1930), Holmes, Pigott, and Campbell (1932), Kempster and Parker (1936), and others.

Lerner (1937) has shown that the shank grows at a more rapid rate than the body as a whole. In connection with the relation of leg length and body weight when plotted on a double log grid, Lerner (1937) states "..... a slight flattening of the line at the extreme weight range is observed in the females due to continued deposition of fat after linear growth has ceased."

The ability to grow fast or slow, which varies from breed to breed and within a breed, is inherited. Schnetzler (1936) was able to develop a fast and a slow growing strain of Barred Plymouth Rocks. The average weight of the sixth generation of Barred Plymouth Rocks at 12 weeks of age raised by him was:

A - Males from fast growing strain - 3.11 lbs.

B - Males from slow growing strain - 2.69 lbs.

C - Females from fast growing strain - 2.65 lbs.

D - Females from slow growing strain - 2.26 lbs.

Lerner (1937) made a very extensive and complete review of growth. He found that the growth of the pectoralis major and the leg bones, as related to the growth of the entire organism, follows a similar course in the Plymouth Rock and the Minorca breeds of chickens. Hybrids between these two breeds, including first generation crosses as well as back crosses, were found to possess the same pattern of growth of the structures studied as the parents. Sex differences were noted in the values of the coefficients of heterogonic growth, since the females, when compared with the males, showed a higher value for the pectoralis major with respect to body weight and a lower value for the leg length with respect to body weight. The basic genetic complex for the type of growth of parts with respect to the growth of the whole was found to be common to the different breeds of poultry studied, with the exception of bantams. While in other breeds tachyauxesis was indicated for muscle and leg bone, he found in bantams bradyauxesis present for leg bones and an approximation to isauxesis in the muscle. It was his opinion that bantams possess growth retarding factors which affect the different parts.

Asmundson and Lerner (1933), applying Minot's formula to purebred White Leghorns and Barred Plymouth Rocks, found significant differences between families for rate of growth at 2 weeks and 8 weeks. They concluded that rate of growth was controlled by multiple genetic factors. Data submitted by Heuser and Andrews (1932), Kempster and Parker (1936), Kempster and Henderson (1923), and others indicate quite clearly that strains of the same variety may differ widely in early as well as in late growth rates.

Sinnott and Dunn (1935) suggest that there are rate-of-growth genes which are capable of controlling development and determining growth gradients.

Five major lines of evidence pointing to the validity of the multifactorial concept are listed by them as follows:

1. The variability of the F2 generation is greater than that of the F1.

2. Genetical distinctness of the F3 progenies from various points on the F2 curve of distribution.

3. Linkage of some genes for quantitative characters with those usually referred to as quantitative characters.

4. Evidence from Datura, that each chromosome may have a bearing on some quantitative trait.

5. Occurrence of the phenomena of heterosis.

Numerous investigations have been made to determine the effects of crossbreeding on rate of growth. Byerly (1930) investigated the size of embryos of the same age and from eggs of the same size from matings of Rhode Island Reds and White Leghorns and reciprocal crosses between the two varieties and found that crossbred embryos grow faster than purebred ones. Henderson (1930) observed little difference in the rate of growth of White Leghorns, Dark Cornish, and their reciprocal crosses. Castle and Gregory (1931) found that crossbred embryos grew faster than purebred embryos.

Gregory, Goss and Asmundson (1935) studied the glutathione concentration at different ages and found it to be positively correlated with fast embryo growth rate and post-hatching growth rate.

Jaap and Morris (1937), Horlacher and Smith (1938), May (1925), Bice and Tower (1939), Waters (1931), Knox, Quinn and Godfrey (1943) each made a series of poultry crosses and found increased acceleration in growth among the hybrids as compared with the purebreds. This increased acceleration in weight was maintained only for approximately 8 to 12 weeks. In the investigations where the F1 generation was raised to maturity, the average weight was approximately the same as the purebred progeny. Where reciprocal matings were reported, except those by Waters (1931), the F1 generation females differed materially in weight, indicating one or more sex-linked genes for rate of growth. However, when the males from the larger breed were crossed with females from the smaller breed, the F1 males also had a tendency to be larger at 10 weeks of age than those from the reciprocal crosses. Axelson (1932) made crosses between three breeds of chickens and found no tendency for rate of growth to be sex-linked. Poffenberger and DeVault (1937) in their analysis of commercial broiler production problems in Maryland, observed that on the average better results were secured from crossbred broilers than from purebred broilers because of the following factors: Less mortality, slightly faster growth as indicated by somewhat heavier weight at selling time -- at 12.6 weeks of age for crossbreds as compared with 13.7 weeks of age for purebreds-- less feed per pound of gain, and a little higher selling price per pound. The efficiency of feed utilization by Barred Plymouth Rocks and crossbred broilers was studied by Hess, Byerly, and Jull (1941). These workers found that crossbreds utilize feed more efficiently on the average than birds of the parental strains.

"Heterosis" or "hybrid vigor," in the opinion of Asmundson and Lerner (1942), is the only valid reason for crossbreeding. If no hybrid vigor is obtained when breeds are crossed, there is usually no advantage in making the cross. The one exception to this may be the crossing of Cornish males on females of other breeds to produce a more attractive carcass.

The rate of growth of crossbred chicks on the average exceeds that of the parent breeds to broiler or fryer weight when the heavier breeds are crossed. When Leghorns and general-purpose breeds are crossed, the crossbreds may exceed both parental varieties to 8 or even 12 weeks of age but after that the heavier breeds are likely to weigh more. At maturity the crossbred progeny are usually intermediate between weights of the purebred progeny. Geneticists have not yet been able to explain why hybridization produces more vigorous offspring.

The results secured from any cross depend largely upon the quality of the parental stocks that are crossed. Little benefit is to be obtained by crossing purebred breeds of poor quality.

Jaap (1941) found that Dark Cornish males mated with females of the heavier breeds produced progeny that weighed more at 12 weeks, but that the purebred progeny from these heavier American breeds were heavier at maturity. The breast conformation of the crossbreds, however, resembled that of the Cornish.

Studies of the effect of inbreeding on growth rate have been made by several research workers. Dunkerly (1930) found little difference between the weights of inbred and outbred birds at sexual maturity. Waters and Lambert (1936) with White Leghorns, Knox, Quinn, and Godfrey (1939) with Rhode Island Reds and Light Sussex, and Godfrey and Marsden (1942) with turkeys secured results which indicate that inbreeding has no appreciable effect on rate of growth. McPhee and Eaton (1931) made an 18-year investigation involving five inbred families of guinea pig control stock, and also animals from crosses between different inbred families. They found that crosses between the light-weight families resulted in a marked increase in growth and weight of the young. Crosses between light-weight and heavy-weight families resulted in young whose growth curves approached or coincided with that of the heavy-weight families, but crosses between the two heavy-weight families did not result in any significant improvement.

Gutteridge and O'Neil (1942) studied Plymouth Rock chickens and found that environment had a much more marked effect upon growth than did heredity during the period of rapid development, and that heredity had a greater effect at 24 weeks and thereafter. Apparently the environmental influence decreased somewhat whereas the influence of heredity became more marked with the approach of maturity.

The deleterious influence of summer temperature on the rate of growth has been discussed by Kempster and Parker (1936) and Kempster (1938 and 1941). They found that maximum temperatures that prevailed during the summer are largely responsible for the retarded growth of late hatched pullets. Even though the retarded growth was most pronounced at the age of 20 weeks, they found that the retarded chicks eventually obtained the same weight as earlier hatched chicks. The absolute size at which growth ceases may be altered by treatment such as feeding.

A close association between rate of growth and rate of feathering has been reported by Martin (1929), Marble (1934), Schnetzler (1936), Jaap and Morris (1937), Radi and Warren (1938), and Godfrey (1942). The breeds of chickens in which the rate of feathering and rate of growth was found by these workers to be correlated include White Leghorns, Buff Orpington, White Wyandotte, Rhode Island Reds, and Barred Plymouth Rocks.

Brody (1927) suggests finally that even though the detailed physiological mechanisms which regulate the lengths of the periods of growth are not weăl understood, it may be said with some degree of certainty that the glands of internal secretion are often the limiting factors in the process of growth and development. Under functioning of the pituitary body, for example, is known to be associated with infantilism, while over functioning with giantism.

Body Size

Marked variations in body size are found between breeds and among chickens of the same breed. Work on the fowl by Keller (1933) shows that cell number and not cell size differences are responsible for these differences in body size. A very thorough review of the research work on body size by Sinnott and Dunn (1935) indicates that in polyploid series, body size is roughly proportional to cell size. Rensch (1923) in contradiction to the workof Keller found not only cell number, but also cell size differences between bantams and larger sizes of poultry. Blum and Gregory (1935) observed that the rate of cell proliferation was relatively greater in the larger sized breeds than in the smaller breeds of fowl.

Different sized chickens have been used by investigators to obtain progeny for studying the inheritance of body size. Jull and Quinn (1931), May and Waters (1927), Maw (1935), Punnett and Bailey (1914), and Godfrey and Quinn (1942), using breeds that differed significantly in adult size, found the adult progeny to be nearer the size of the smaller parental breed, suggesting that possibly there are dominant genes for small body size.

Punnett and Bailey (1914), Kopec (1927), Warren (1927), and Waters (1937) worked with breeds of chickens that did not differ significantly in body size. In practically all cases, the size of the F1 progeny from such crosses was about midway between the parental breed sizes or slightly nearer the larger-sized breed. In all of these crosses from which an F2 generation was secured there was greater variability in the F2 than in the F1 generation. All of these investigations demonstrate that the inheritance of body size is complex and depends upon a great many factors.

Maw (1935) observed that in crosses between Light Brahmas and Golden Sebright Bantams a sex-linked gene was associated with size inheritance. Using measurements of bone length as a criterion, he observed that the difference in size between the two parents was due to some extent to a sex-linked factor. Not only was there a difference between reciprocal cross females, but a study of the F2 population revealed indications of linkage of genes for size with two of the genes located on the sex chromosome, which were present in his stock. These results are of great significance, not only because they constitute the first definite confirmation of Mendelian inheritance of size in poultry, but also because they indicate the presence of a size-limiting factor in bantams, which may be of a dominant nature. Evidence of sex-linkage in the inheritance of body size is also indicated in the results secured from the crosses made by May (1925), Warren (1930), Knox and Olson (1938), and Knox (1939). The F1 females secured from each of the reciprocal crosses differed materially in weight. It was also noted that in crosses in which the male parent was of the larger parental breed and the female parent was of the smaller parental breed, the F1 males were usually larger at 10 weeks of age and later than F1 males secured from reciprocal crosses.

The investigations which have been made of the inheritance of adult body size indicate that there are genes that have a particular effect on certain body parts as well as many genes that affect the size of the body as a whole. The inheritance of the Creeper character studied by Landauer and Dunn (1930), rumplessness reported by Dunn (1925) and Davenport (1906), and the statistical analysis of bone length by Wright (1932) and of inbred White Leghorns developed by Dunn (1928) are specific examples.

Body size may be expressed in terms of body weight or in terms of some skeletal measurement. Mature length of shank has been found to be of use in expressing size differences. Jaap (1938) has shown that shank length (tarsometatarsus) serves as a good index of skeletal size and that in females shank length remains constant after five months and in males after six months. It is possible, therefore, to select females and males, respectively, at these ages, that will develop into the size of bird required at maturity. Shank length in males is reported by Jaap (1938) to be 25 percent greater than shank length in females and body weight in males is 35 percent greater than body weight in females of approximately the same age.

Lerner (1937) observed that the length of the shank in live birds is a good index of inherent body size. The length of shank and body weight were observed by Lerner (1939) to be more closely correlated in growing than in mature birds.

Asmundson (1944) calculated the coefficients of correlation for body weight and shank length, keel length, depth of body taken from the anterior point of the ilium to the keel, width of breast at 1, 2, 3, 4, and 5 cm. above and 2 cm. back of the anterior point of keel on 3 strains of live turkeys at 24 weeks of age. He found that the correlations are as high or higher between body weight and linear measurements as they are between the various linear measurements. The correlations reported indicate that the various measurements are all affectdd to some extent by body weight.

Investigations by Hadley and Caldwell (1920), Asmundson (1921), Atwood (1923), Jull (1924), and Hall and Marble (1930) indicate that body size is also correlated with egg size.

Body Shape

Considerable variability in body shape and degree of fleshing is exhibited by all sizes and ages of chickens sold for meat. This indicates that very little has been accomplished from the standpoint of breeding for uniformity of market type.

Huxley (1932) says that only animals in which organs are growing at the same rates will preserve their form unchanged with increase of size and that few if any animals can be found in which some organs do not grow at a different rate from the body as a whole. Sinnot and Dunn (1935) suggest that the genetic control of shape may be vested in relative rates of cell division in different parts of the body or organ, in cell shape or in the plane of cell division. Lerner (1939) states that shape is a function of the rate and time or duration of growth from the beginning of growth of any particular dimension to the time of its approach to the upper asymptote. A cross section or ratio taken at any point in time does not permit us to judge of the genetic differentials involved either in the final shape or in the conformation at any given time. He contends that more attention should be centered on the processes leading to the assumption of the specific form rather than at the end products themselves.

Some of the first investigations on the inheritance of body form in the domestic fowl were those of Kopec (1927) who crossed White Leghorns with Buff Orpingtons. He observed that the Buff Orpingtons had longer tibiotarsi and tarsometatarsi than the White Leghorns and that the length of these bones in the hybrids more nearly approached the long-boned parent. Ghigi and Taibell (1927) observed that in an Indian Game x Leghorn cross the tarsi of the F1 generation were of the same length as that of the longer-boned parents. Latimer (1927) found that the rate of the growth of the leg bones in the fowl is higher than the rate of body weight growth and that the male bones increase from hatching time to maturity to a greater extent than do female bones, with the exception of the femur in which case no difference in rate of growth was observed. Lerner and Asmundson (1932) made matings of Ancona x Light Sussex and observed that up to twelve weeks of age there was a significant difference in the length of the tarsometatarsi between the two types of backcross progeny in favor of the Light Sussex x F1 mating.

Schneider and Dunn (1924) reported that body weight is from three to six times as variable as bone measurements. They also observed that the humerus, ulna, femur and tibiotarsus were 16 percent longer in the males than females.

Lerner (1937) suggested tarsometatarsus (shank) length as a criterion of size. By using a measuring device, designed by Burmester and Lerner (1937), Lerner was able to measure accurately the length of the tarsometatarsus on live birds. He obtained a correlation of 0.968 between the live measurement and the actual length of the bone.

Lerner (1939) has reported a correlation coefficient of 0.659 ± 0.032 between live body weight and shank length in Single Comb White Leghorn females. Shank length and body weight at 4, 8, 12 and 16 weeks were studied in progeny of Barred Plymouth Rocks and Barred Plymouth Rock and Single Comb White Leghorn crosses. It was concluded that shank length and body weight at an early age are interchangeable as the independent variable in the determination of body weight at a later age, also that body weights and shank length are more closely correlated during the growing stages than they are in mature birds. Investigations by Wright (1918) and Dunn (1928) show that many genes are involved in the inheritance of bone length with some of the genes having a cumulative effect on the growth of certain parts only.

Jaap (1938) found that shank length serves as a good index of skeletal size. Jaap and Penquite (1938), in a study of body conformation in the fowl, concluded that differences in the conformation of the live fowl could be measured accurately by comparing body weight, shank length, keel length and anterior body depth. The relation between shank length and body weight was reported as the most suitable single criterion of body conformation. Growth in shank length was found to cease at six months for males and five months for females. They also observed that the most desirable measure of body shape in live birds is the relationship between cube root of the body weight and the length of shank. However, Lerner (1941) and Schmalhausen (1927) point out that the third power of linear measurements or reciprocally the cube root of body weight as a component of indices of conformation and fleshing would hold true only if growth were isometric between the dimensions studied and body weight. Bird (1943) mentioned that it appeared that all birds which were adjudged to show a superior degree of fleshing by the ratios were at the same time those that reached the greatest average body weight. He found the entire musculature dissected off the pectoral region in Barred Plymouth Rock and White Leghorn roasters was closely correlated to the deviation observed from expected body weight as related to length of tibia. Although Bird used tibia measurements, he obtained a very high correlation between tibia and tarsometatarsus length. Quisenberry, Roberts, and Card (1941), in a statistical study of the bones of the skeleton of the fowl as related to mature body weight, found a close relationship between skeletal measurements and mature weights.

Maw and Maw (1938) and Jaap and Thompson (1940) observed that the body of the sire is transmitted to his progeny. In their studies on heritable differences in adult female body conformation, they were not able to demonstrate any consistent relation between proportional length of shank and keel and proportional anterior body depth.

Maw and Maw (1939) found an increase in length of leg led to decrease in the percent of edible flesh, and that an increase in the circumference of the tibial muscle gave an increase in the percent of edible flesh. The influence of the breed has been reviewed by Maw (1939), who found differences inthe relative proportion of edible meat, fat, and skin to bone and waste products in the dressed carcass. He also observed that the percentage of flesh on the carcass is influenced by the size of the stock as related to the stage of growth. The effect of management has been reported by Harshaw (1938) who found differences in the amount of total edible meat between roasters grown on range and those confined and between fattened and unfattened stock.

Knox and Marsden (1944) made observations for breast type, live body weight at 24 weeks of age and shank length in four different varieties of turkeys. All three characters were found to exhibit a blending type of inheritance in F1 and F2 typical of quantitative characters. Asmundson (1944) determined the length of the shank, length of keel, depth of body, width of breast, and live weight of three strains of Bronze turkeys at 24 weeks of age which exhibited different degrees of fleshing. The three strains differed significantly in weight of bird, length of keel, depth of body, and width of breast. Values of r based on the totals show that the weights and measurements considered were significantly correlated. Bird (1943, 1944, 1945) studied the fleshing characteristics in chickens, pheasants and turkeys and observed that a shallow torso relative to volume of muscle tends to produce a rounded breast. Additional studies on body measurements in relation to degree of fleshing and body conformation in turkeys in which results similar to those discussed were obtained have been made by Jaap (1938), Jaap and Penquite (1938), Jaap, Thompson and Milby (1939), Payne (1938), Darrow and Morgan (1944), and Dolecek, Wilson, and Poley (1941).

Breast Meat

Dolecek, Wilson and Poley (1941) used what was termed a B instrument to determine breast width (W), breast depth (D), and breast angle (P) on 31-week-old Rhode Island Red roasters. The bodies of 64 birds were cut longitudinally and in each case the breast area of one-half was calculated from measurements taken 5/8 of an inch from the anterior tip of keel bone as follows: W/2 (D plus A minus P) - DV, where W = Breast width, D = breast depth on one side, A = breast depth at Center, p = Plunger reading, and V = plunger depth. The volume of breast was calculated from this area by multiplying the breast area by breast length. They obtained the following correlations between breast area and meat removed from the breast:

1 - Breast area and weight of light meat - 0.42

2 - Breast area and weight of total edible meat - 0.44

3 - Breast volume and weight of light meat - 0.59

4 - Breast volume and weight of total edible meat- 0.64

It is apparent that Dolecek and his co-workers did not obtain the true volume of breast because the breast approaches a conic section in shape, the pointed end being at the rear end of the breast. Correlations of -0.10 and -0.33 were obtained between the weight of light meat and total edible meat, and the shank length divided by the cube root of body weight suggested by Jaap as an index of fleshing. This agrees with the work of Scott (1940), who states that he was unable to find a positive correlation between meat measurements describing full fleshing in roasters and the "fleshing index" recommended by Jaap.

Bird (1943) removed the edible meat from 50 Barred Plymouth Rock and 66 White Leghorn cockerels at 29 weeks of age and obtained a correlation of 0.942 between starved live weight and total edible meat. On correlating the various skeletal measurements, Bird found that the length of all long bones bears a close relationship one to the other - their correlations being of the order of 0.8. All other bones were found to be poorly correlated and he concluded that length of the long bones determines body size more consistently than any other skeletal measurement.

Lerner (1937) dissected 760 Barred Plymouth Rocks, Black Minorcas, first crosses between them, and backcrosses and found that the relative growth constants for the weight of the breast muscle and the length of the long bones are the same. In (1941), Lerner dissected 179 Single Comb White Leghorns, Rose Comb Black Bantams, and reciprocal crosses between them and found that the growth constants for the breast muscle and legbones in the bantams are of the same magnitude as in the Leghorns, Barred Plymouth Rocks, and Minorcas.

Jull, Phillips and Williams (1943) selected short and long-shanked 12-week old New Hampshire cockerels and compared the breast meat with shank length in the two lots. There were an average of 195.5 grams of breast meat on the short-shanked compared with 197.5 grams of breast meat on the long-shanked cockerels. Harshaw (1938) made an analysis of the quantity of breast meat on crossbreds in relation to live and dressed weight. An average of 134.3 grams of breast meat was present on the birds killed at 12 weeks of age. This was 13.5 percent of the live weight of the unfattened birds. He observed further that the percent of breast muscle and leg muscle decreased with fattening while the percentage of the remaining edible portion increased. The ratio of leg muscle to dressed weight increased with age, but the ratio of the breast muscle to dressed weight remained practically the same. Jaap and Penquite (1938) used wire solder to measure breast width on live and dressed birds at a point 1½ inches above the point of the keel. They found this measurement useful in predicting market conformation and grade.

Lloyd and Clandinen (1937) and Lloyd (1940) reported improvement in market conformation of two breeds obtained by the method of selecting breeding birds on the basis of birds possessing U-shaped, V-shaped, and I-shaped breasts. It is apparent from such progress that breast shape is dependent on quite a number of genes. Harshaw, Kellogg, Rector and Marsden (1943) report that turkeys from a broadbreasted strain of Bronze had a higher percentage of breast muscle than other strains.

The F1 and F2 progeny of the Beltsville Small White crossed with Broad-Breasted Bronze turkeys by Asmundson and Lerner (1942) had an average breast type intermediate between that for the parental strains used. These observations on live birds confirm the data of Harshaw, et al on ratio of breast muscle to dressed weights. The breast muscle averaged a little more than 22 percent of the dressed weight in the Broad-Breasted Bronze, a little more than 19 percent in the Beltsville Small White, and slightly more than 18 percent in the White Holland and in the Standard Bronze. Asmundson (1944) concluded that actual length of shank, length of keel, and depth of body are inadequate to differentiate strains of turkeys studied, whereas direct measurement of breast width at 1 cm. above the lower surface of the keel are adequate for this purpose. The data he obtained indicate that the difference in breast width of the two strains at 24 weeks is determined by more than one pair of genes, that the genes are autosomal and that at least some of the genes act independently of genes for weight and size. There appeared to be no dominance of genes influencing width of breast. It is Asmundson's opinion that the Broad-Breasted Bronze turkey is the result of the gradual accumulation by selection of genes for greater width of breast. Marsden (1939), and Knox and Godfrey (1940) established a strain of small white turkeys with desirable breast conformation within five years. This new breed, the Beltsville Small White, was produced to meet a definite market need, the specifications having been clearly defined before the project was undertaken. From the breeder's point of view, selection will work to produce desired modifications in breed characteristics in all instances wherein there is a definite correlation between genotype and phenotype. The exact delimitation of the genetic mechanism is not needed for breed improvement to be achieved.

Market Grade

Twenty-nine week old Barred Plymouth Rock and White Leghorn cockerels were killed, dressed, graded, and frozen by Bird (1943). A transverse section of the frozen carcass 5/8 mm. thick immediately forward of the anterior point of the keel was sawed out and a careful tracing was made of its posterior face on paper. The relative roundness of these sections was repeatedly found to coincide almost perfectly with the rank numbers of carcass that had been aligned or graded.

Gutteridge and O'Neil (1942) measured breast angle by a special instrument consisting of steel bands adjustable by screws and capable of being closely fitted to the flesh of the breast. It was found that the calculated figures for the breast angles of different birds very closely approximate the grading rating for conformation of breast. Dolecek, Wilson, and Poley (1941) obtained a significant correlation between alignment grade and the fleshing index developed by Poley (1940) in Rhode Island Red Cockerels. Jaap (1938) obtained poor agreement between commercial grading and his fleshing index. Scott (1940) and Dolecek et al (1941) obtained similar results.

Hoffman (1943) raised 100 White Rocks and 100 White Cornish x White Rock Crossbreds to 14 weeks of age when they were graded into AA, A, B, and C grades on the basis of fleshing and body conformation. Eighty-one percent of the crossbreds compared with 72.7 percent of the purebreds graded AA and 2.5 percent of the crossbreds compared with 4.2 percent of the purebreds graded C. Similar results were obtained by Tulley, Neil, Schroeder and Wesley (1942).

Knox and Marsden (1944) developed a suitable method for grading turkeys for breast development by a combination of impressions gained through touch and sight. Bird (1943) found a rather low correlation between grade and the absolute weight of edible meat and also that commercial grading has a pronounced tendency to award superior grading to high quality carcasses and inferior grading to poor ones. Even so, it is his opinion that routine grading serves as a fair estimate of market value and will continue to be indispensable to commercial practice for reasons of speed and convenience.

MATERIALS AND METHODS

The chickens in this study were hatched at the University of Maryland in 1941 from eggs laid in trapnests by Cornish, New Hampshires, Barred Plymouth Rocks, and their crosses. Approximately half of these progeny were produced from natural matings and the remaining half came from purebred and F1 females impregnated artificially. The breeding stock used in 1941 to produce the F2 and backcross progeny was produced from matings made the previous year and the balance of the 1941 progeny, purebreds and crossbreds, came from matings containing birds representing the same strains of Cornish, New Hampshire, and Barred Plymouth Rocks used in 1940. The F1 Cornish x New Hampshire and the F1 Cornish x Barred Plymouth Rock adult males and females used in the 1941 matings were not noticeably larger in size than the adult purebred parents, but the breast conformation of the adult crossbreds resembled that of the Cornish.

The progeny from these matings were wingbanded at the time they were hatched, fed the Maryland Experiment Station mash containing approximately 21 percent protein, and raised in starting and growing batteries until they were 12 weeks of age, when they were large enough to be marketed. Effort was made to provide the same environmental conditions for each lot of chicks hatched twice each week from these different matings.

Feed was removed from the hoppers the day each group of birds was 12 weeks old. The market grade, body measurements, and the live weight of each bird were carefully determined within the 24-hour period which followed, during which time the birds received no feed.

Each live bird was examined for size, body conformation, and fleshing condition, and graded according to the specifications described in the Tentative U. S. Standards for Quality for Live Poultry as revised

April 1, 1937 as follows:

Birds with exceptionally well-proportioned bodies, extra broad, fully-fleshed breasts, and relatively short, meaty legs were classified as "AA quality grade;" birds with well-proportioned bodies, broad, well-fleshed breasts and meaty legs were classified as "A quality grade;" birds with fairly well-proportioned bodies, fairly broad, fairly well-fleshed breasts and legs that were fairly meaty were classified as "B quality grade;" and birds with poorly-proportioned bodies, narrow, poorly-fleshed breasts and poorly-meated legs were classified as "C quality grade." All thin, emaciated birds unfit for human consumption were classified as rejects.

Each bird was then suspended from a shackle and accurate measurements taken of the breast, the depth of body and the length of shank. A few feathers were plucked from a small cross-section area of the breast and a thin strip of lead, 3/4 of an inch in width, capable of holding its shape when removed from an irregular surface, was fitted closely over the breast of each bird, at a point 1-1/2 inches from the anterior end of the keel and extending down along each side of the body. The ends of this lead tape were then bent outward on each side of the body at a point just below the breast feather tract and directly over the lateral caudal process on each side of the sternum. These two anatomical points were easy to find after the birds had been starved. (See Figure 1) These are believed to be reliable points from which to determine the width, depth, and the cross-sedtion area of the breast because frozen carcasses of different sized birds sawed in half, through this plane of the body, indicated that the breast meat on the body extended upward from the sternum toward the back as far as these two anatomical points. (See Figures 3 and 4). The lead tape was then removed and an outline showing the shape, fullness, width, and depth of breast was traced on cross section paper.

Figure 1. Strip of lead fitted closely over breast of live bird

The width of breast was then determined by measuring the distance between the points, on this outline, corresponding to the lateral caudal process on each side of the body. (See (a) Figure 2) This method is similar to that used by Asmundson (1944), Jaap and Penquite (1938), and Payne (1938) in determining the width of breast in turkeys.

The depth of the breast was obtained by measuring the perpendicular distance from the topmost part of the breast outline to the line below from which the width of the breast was determined. (See (b) Figure 2)

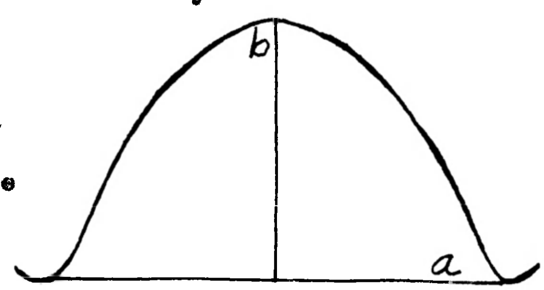


Figure 2. Cross-section Area of Breast

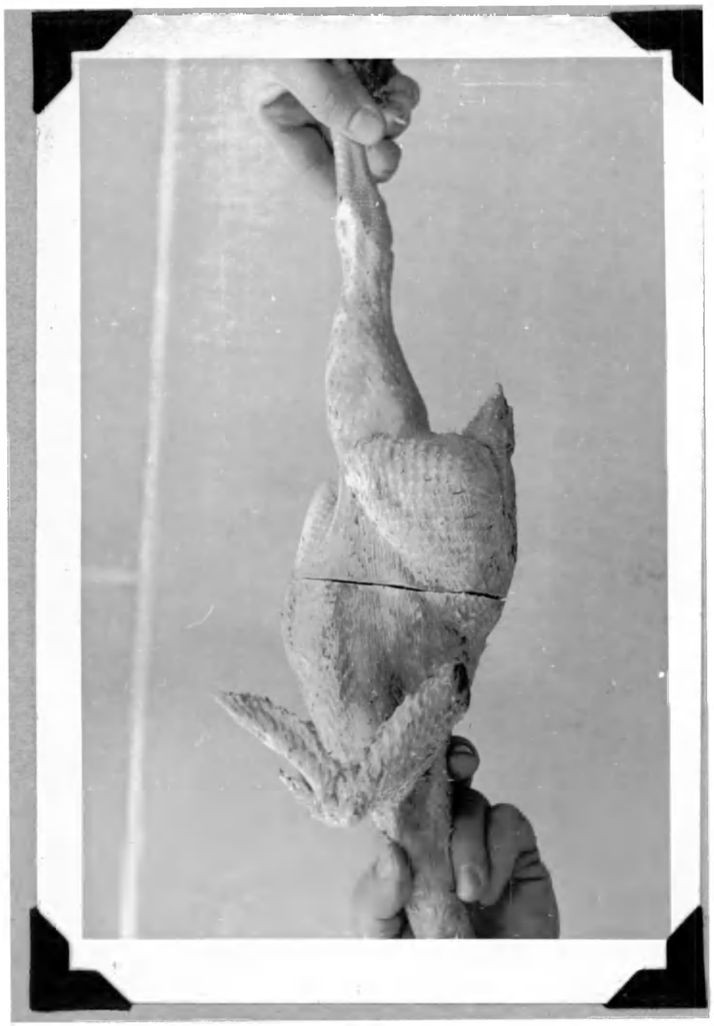


Figure 3. Plane at which frozen dressed carcass was bisected to observe lateral caudal processes

Figure 4. Posterior half of frozen carcass showing lateral caudal process on each side of sternum

A planimeter was then used to determine the cross-section breast area or plane of the breast in square centimeters from this outline.

A method somewhat similar to this was used by Bird (1943) for determining the relationship between the roundness of body and alignment grades in chicken carcasses.

A vernier Caliper graduated in millimeters was used to obtain the body depth or distance from the anterior point of the ilium to the keel, (see Figures 5 and 6), the length of each bird's keel (see Figures 7 and 8), and the width of the shoulder. (See Figure 9)

This Caliper was also used to obtain the length of shank, using the method described by Jaap (1938). (See Figures 10 and 11) Each bird was carefully weighed on a Toledo scale and the weight in grams recorded.

Two hundred and fifty-six representative birds, 110 males and 146 females, from the various matings were then killed as the different groups reached 12 weeks of age and the breast meat was carefully removed from each with a scalpel. A Toledo balance was used to determine the exact number of grams of meat present on the breast of each of these birds.

Some of the birds in the breeding pens which could not be replaced were stolen while this study was in progress. For this reason, the progeny from certain matings which should have been included are missing and the number of progeny in other instances is somewhat limited.

All of the work associated with the production, wingbanding and rearing, the grading and weighing, measurement of the body parts, the dissection of the pectoralis major, and recording of these data was done by the writer. The data thus obtained were then subjected to statistical analysis.

Figure 5. Measurement of body depth
of live bird

Figure 6. Measurement of body depth
of dressed carcass

Figure 7. Measurement of keel length of live bird

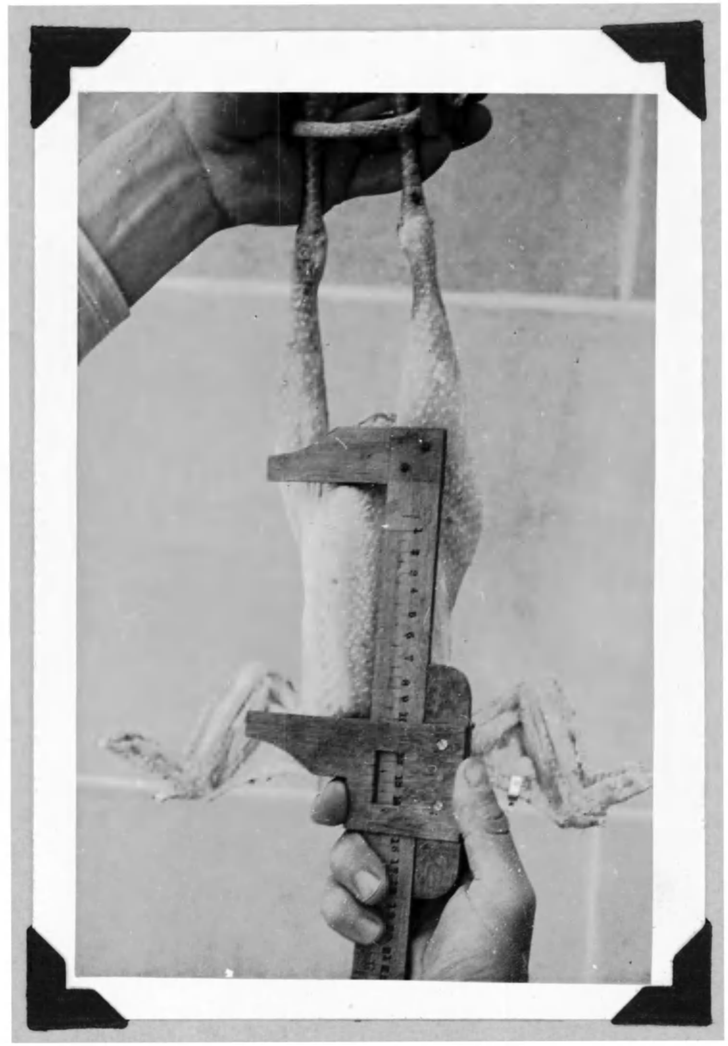


Figure 8. Measurement of keel length of dressed carcass

Figure 9. Measurement of shoulder with of live bird

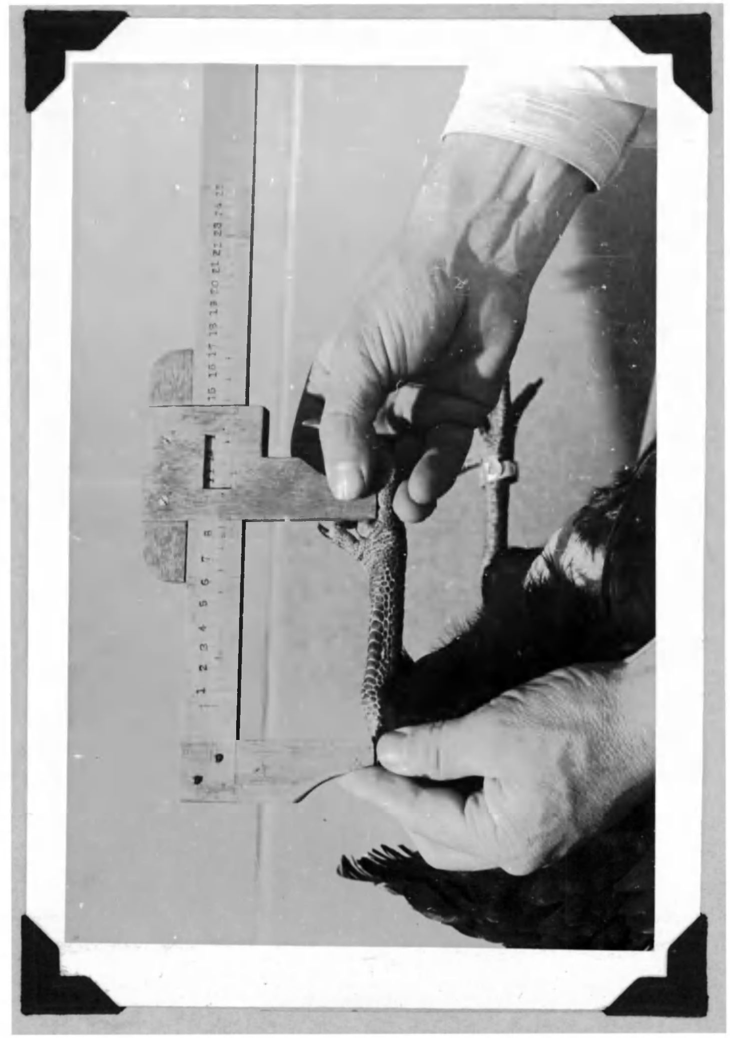


Figure 10. Measurement of shank length of live bird

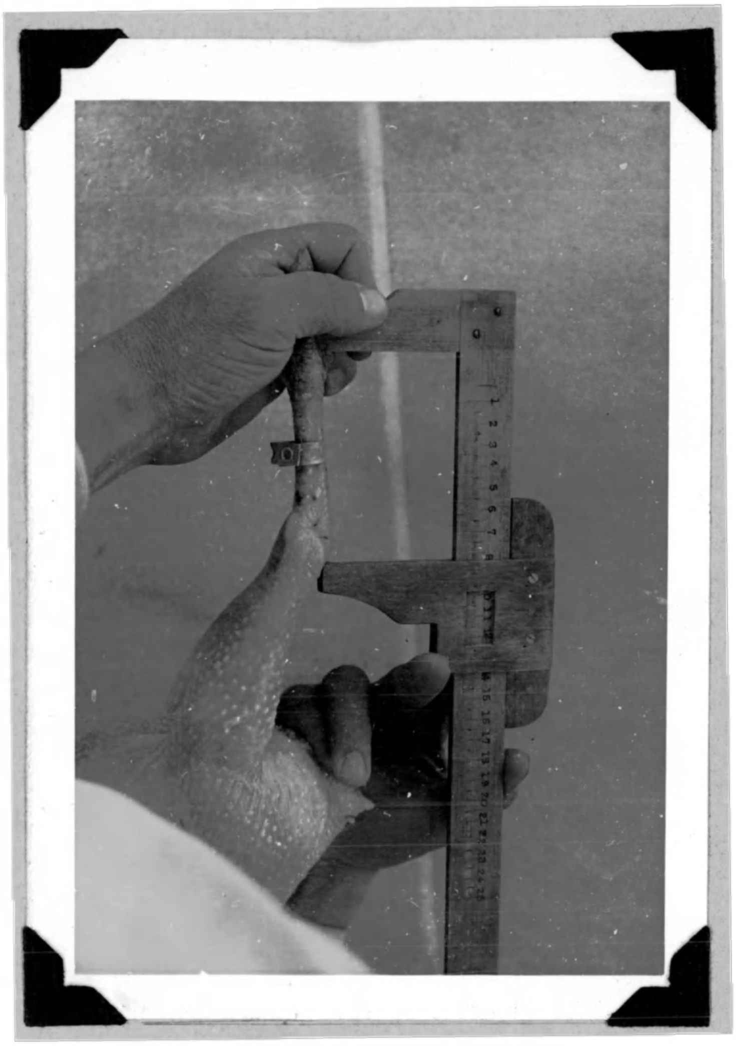


Figure 11. Measurement of shank length of dressed carcass

ANALYSIS OF DATA

The data from these investigations were grouped together according to the sex and ancestry of the progeny and statistical procedures recommended by Croxton and Cowden (1941) and Mills (1938) were employed for making analysis, comparisons, and deductions.

The mean values and standard errors were determined by sex for live weight, amount of breast meat, and body measurements. The percent of live weight represented by breast meat was also determined for all breeds as well as for the males and females.

A series of scatter diagrams were prepared at the outset to obtain an estimate of the relationship of breast meat to live body weight, observed cross-section area, breast index, and each of the body measurements. The breast index in this study was determined by dividing the result obtained from dividing the observed cross-section area by the triangular breast area, by the result obtained from dividing the depth of breast by its width. The depth and width of breast were used in this determination in this manner because of their close relationship to the observed cross-section and triangular areas of the breast.

Coefficients of correlations and standard wrrors were then determined between the amount of breast meat and the different body measurements which appeared most promising on the scatter diagrams. The equation $Y = a + bx$ was used, and the constants a and b were solved by means of the least squares method. Correlation ratios between live body weight, breast meat, body measurements, and grade were determined for each sex by Carl Pearson's method.

Mean live body weights and mean breast widths were obtained for all the progeny produced from each of the different purebred and crossbred matings. Data for a total of 292 males and 428 females were included in this part of the analysis.

The mean amount of breast meat, the percent breast meat of live weight, and the mean breast index were determined for the progeny from the purebred and crossbred matings from which the breast meat had been removed.

Tables were prepared showing the distribution of the 12-week old purebred and crossbred progeny for each of these respective groups of progeny, according to sex and market grade. The mean cross-section breast areas and mean breast widths for the progeny from each of these purebred and crossbred matings were obtained and graphs were prepared showing these data for the F1 progeny produced from the Cornish x New Hampshire, Cornish x Barred Plymouth Rock, and the backcross progenies obtained from F1 males of the crosses mated back to purebred New Hampshire and Barred Plymouth Rock females, respectively. Tables showing the percent of these progenies by grade and the absolute number from each mating according to sex were also prepared.

Finally, data for the progenies secured from four New Hampshire and four Barred Plymouth Rock females mated to the same Cornish male were also studied to determine differences in live body weight, breast width, breast index, amount breast meat, market grades, and the percent breast meat of live body weight.

EXPERIMENTAL RESULTS

Mean Values and Relationship of Body Measurements

The mean values of live body weight, amount of breast meat, and other measurements related to body conformation and market condition for the 256 twelve-week old purebred and crossbred progeny in this study are given in Table I. The degree of variability in these values is greatest for the live body weight and smallest for the shank and keel lengths. Similar observations were made by Schneider and Dunn (1924).

The difference in the mean live body weight between the males and females is significant. The mean values of breast depth, body depth, keel length, shank length, observed cross-section breast area and the ratio of shank length to cube root of body weight tended to be greater in the males than in the females. The mean values of the amount of breast meat, breast width, and breast index are slightly larger in the females than in the males.

The mean value of the shank length was only slightly larger than the mean keel length in these progeny. This is of interest because Payne (1938) observed the same relationship between these two linear measurements in Bronze Turkey toms at 33 weeks of age.

The ratio between shank length and the cube root of body weight was 0.91 $\pm$ 0.01 for all birds, 0.93 $\pm$ 0.01 for males, and 0.89 $\pm$ 0.01 for the females. High ratios between shank length and live body weight have been reported in growing chickens by Lerner (1937), in mature chickens by Jaap (1938), and in growing turkeys by Asmundson (1944). The breast meat was 10.59 percent of the live weight in these 256 progeny, 9.96 percent in the males, and 11.12 percent in the females.

TABLE I

Mean Live Weight, Breast Meat, Body Measurements in 256 12-week old Purebred and Crossbred Progeny, Including 110 Males and 146 Females

Measurement	Mean Values and Standard Errors		
	Both Sexes	Males	Females
Live weight (gms.)	989.22 ± 15.72	1041.16 ± 25.25	950.09 ± 19.35
Breast meat (gms.)	104.85 ± 2.25	103.73 ± 3.63	105.69 ± 2.85
Breast depth (cm.)	3.13 ± 0.21	3.16 ± 0.37	3.10 ± 0.30
Body depth (cm.)	10.68 ± 0.08	10.95 ± 0.11	10.48 ± 0.11
Keel length (cm.)	8.59 ± 0.06	8.77 ± 0.08	8.46 ± 0.08
Shank length (cm.)	8.94 ± 0.06	9.27 ± 0.11	8.70 ± 0.08
Breast width (cm.)	4.50 ± 0.30	4.53 ± 0.52	4.57 ± 0.30
Observed cross section breast area (sq. cm.)	8.75 ± 1.16	8.76 ± 1.80	8.73 ± 1.57
Breast index	1.76 ± 0.16	1.75 ± 0.22	1.79 ± 0.16
$\sqrt[3]{\frac{\text{Shank length}}{\text{Body weight}}}$	0.91 ± 0.01	0.93 ± 0.01	0.89 ± 0.01

With the exception of the mean value of shank length, divided by the cube root of body weight, which Jaap (1938) reported was a good index of fleshing, all of the simple coefficients of correlations between the amount of breast meat and the body measurements reported in Tables II and III are highly correlated. These data indicate that in general the larger the bird, the greater the amount of breast meat on the carcass. This is in accord with the common belief that the largest bird usually has the largest component parts.

These data also indicate that regardless of sex, the larger the bird, the greater the amount of breast meat. This agrees with the investigations made with chickens by Harshaw (1938), and with turkeys by Harshaw, Kellog, Rector, and Marsden (1943) and Asmundson and Lerner (1942). None of the bone measurements appeared to be as highly correlated with the amount of breast meat as the live body weight. This suggests that there may be separate genes for the development of bone and muscle tissue.

Shank length gave a slightly higher correlation with breast meat than the other bone measurements. This is to be expected, since shank length is more highly correlated with live body weight than the correlation between other bone measurements and live body weight and since live body weight appears to be the best measure of breast meat in this investigation. Similar observations on the relation between shank length and amount of breast meat have been made by Harshaw (1938), Lerner (1939b), Bird (1942), and Jull, Phillips, and Williams (1943).

Breast index did not prove to be a very good measure of either the amount of meat on the breast or the market grade (see Table IV).

The shank length-body weight ratio also proved to be a poor measure of breast meat in this study. Similar conclusions have been made by Dolecek, Wilson, and Poley (1941) and by Scott (1940).

TABLE II

Coefficients of Correlation Between Amount of Breast Meat and Body Measurements in 256 12-week old Purebred and Crossbred Progeny, Including 110 Males and 146 Females

	Coefficients of Correlation		
Measurement*	Both Sexes	Males	Females
Live weight	.91 ± 0.01	.93 ± 0.01	.92 ± 0.01
Shank length	.78 ± 0.02	.73 ± 0.04	.82 ± 0.02
Body depth	.76 ± 0.02	.77 ± 0.03	.65 ± 0.02
Observed cross section breast area	.76 ± 0.02	.83 ± 0.03	.71 ± 0.04
Keel length	.74 ± 0.02	.72 ± 0.04	.85 ± 0.02
Breast width	.61 ± 0.03	.58 ± 0.06	.66 ± 0.04
Breast depth	.53 ± 0.04	.62 ± 0.05	.48 ± 0.06
Breast index	.44 ± 0.06	.44 ± 0.07	.44 ± 0.06
$\sqrt[3]{\frac{\text{Shank length}}{\text{Body weight}}}$	.21 ± 0.05	.28 ± 0.08	.22 ± 0.07

* All measurements were correlated with amount of breast meat.

TABLE III

Order of Relative Value of Coefficient of Correlations between Breast Meat and Body Measurements in 12-week old Males and Females, Respectively

110 Males		146 Females	
Measurement	Coefficient of Correlation	Measurement	Coefficient of Correlation
Live weight	.93 ± 0.01	Live weight	.92 ± 0.01
Observed cross section breast area	.83 ± 0.03	Keel length	.85 ± 0.02
Body depth	.77 ± 0.03	Shank length	.82 ± 0.02
Shank length	.73 ± 0.04	Observed cross section breast area	.71 ± 0.04
Keel length	.72 ± 0.04	Breast width	.66 ± 0.04
Breast depth	.62 ± 0.05	Body depth	.65 ± 0.02
Breast width	.58 ± 0.06	Breast depth	.48 ± 0.06
Breast index	.44 ± 0.07	Breast index	.44 ± 0.06
$\sqrt[3]{\frac{\text{Shank length}}{\text{Body weight}}}$	.28 ± 0.08	$\sqrt[3]{\frac{\text{Shank length}}{\text{Body weight}}}$	.22 ± 0.07

Another interesting observation in these data, (Table III), is that the order of relative value of the coefficients of correlations between breast meat and body measurements is not the same in the two sexes. The correlation between breast meat and shank length, keel length, and breast width, respectively, was higher in the females than in the males, while the correlation between breast meat and live body weight, the observed cross-section area, body depth, and breast depth, respectively, was higher in the males than in the females.

Market Grades in Relation to Various Body Measurements

The mean values for the different body measurements under consideration are presented by grades and for sex in Tables IV, V, and VI. The correlation ratios between live weight, breast meat, body measurements and grade as determined by Carl Pearson's Method are also given for males and females.

The mean values for each measurement in these tables appear to follow the same general pattern so far as market grade is concerned. Except for the shank length-body weight ratio, the mean values for each measurement decrease in magnitude with each decrease in grade. For example, the mean value of live weight for the A grade male progeny is 14 percent smaller than the AA grade male progeny, the mean value of live weight for the B grade male progeny is 18.8 percent smaller than the A grade male progeny, and the mean value of live weight for the C grade male progeny is 17.6 percent smaller than the B grade male progeny. Since the Tentative U. S. Standards for Classes and Grades for Live Poultry now provide for U. S. Grade #1 and U. S. Grade #2 live poultry, and the AA, A, and B grades, in use when this study was made, are now all included

TABLE IV

Mean Values and Correlation Ratios Between Live Weight, Breast Meat, Body Measurements and Grades in 256 12-Week Old Purebred and Crossbred Progeny, Including 110 Males and 146 Females

Mean Values for "Males"

Grade	Per Cent	Number Progeny	Live Weight (gms.)	Breast Meat: Weight (gms.)	Breast Meat: % of Live Weight	Shank Length (cm.)	Keel Length (cm.)	Body Depth (cm.)	Breast Depth (cm.)	Breast Width (cm.)	Breast Index	Observed Cross-section Breast Area (Sq. cm.)	Shank length / $\sqrt[3]{\text{Body weight}}$
AA	12.73	14	1385.07	155.57	15.55	10.37	9.28	11.96	3.44	5.26	2.00	11.95	.94
A	29.09	32	1190.75	128.71	10.80	9.77	9.24	11.60	3.30	4.69	1.78	9.71	.94
B	33.64	37	967.08	91.05	9.41	9.02	8.66	10.72	3.15	4.46	1.68	8.35	.91
C	22.73	25	797.20	66.28	8.31	8.43	8.07	9.92	2.84	4.08	1.64	6.60	.91
R	1.81	2	660.50	44.00	5.00	8.47	8.15	10.43	3.20	3.85	1.16	5.91	.97
Total	100.00	110	1041.16	103.73	9.96	9.27	8.77	10.95	3.16	4.53	1.73	8.76	.93
Correlation ratios@			0.74	0.80	—	0.53	0.50	0.56	0.49	0.63	0.51	0.87	-0.08

Mean Values for "Females"

Grade	Per Cent	Number Progeny	Live Weight (gms.)	Breast Meat: Weight (gms.)	Breast Meat: % of Live Weight	Shank Length (cm.)	Keel Length (cm.)	Body Depth (cm.)	Breast Depth (cm.)	Breast Width (cm.)	Breast Index	Observed Cross-section Breast Area (Sq. cm.)	Shank length / $\sqrt[3]{\text{Body weight}}$
AA	15.75	23	1168.60	138.86	11.88	9.40	9.26	11.51	3.49	5.06	1.86	11.39	.89
A	31.51	46	1065.45	123.00	11.54	9.10	8.86	11.03	3.18	4.63	1.84	9.39	.89
B	35.62	52	897.69	97.65	10.87	8.56	8.31	10.37	3.05	4.33	1.76	8.23	.88
C	15.07	22	682.18	64.77	9.49	7.85	7.42	8.90	2.72	3.96	1.70	6.36	.89
R	2.05	3	379.00	25.66	6.77	6.13	6.42	7.46	2.43	3.46	1.47	4.37	.84
Total	100.00	146	950.09	105.69	11.12	8.70	8.46	10.48	3.10	4.57	1.79	8.73	.88
Correlation ratios@			0.73	0.74	-	0.58	0.62	0.67	0.57	0.76	0.37	0.83	0.05

@ As corrected by Carl Pearson's Method.

TABLE V

Percentage Decrease in Size of the Mean Values for Each Sex and Body Measurement by Market Grade

Data for 110 Male Progeny

Changes in Grade	Live Weight	Breast Meat Weight	Breast Meat % of Live Weight	Shank Length	Keel Length	Body Depth	Breast Depth	Breast Width	Breast Index	Observed Cross-section Breast Area	$\sqrt[3]{\frac{\text{Shank length}}{\text{Body Weight}}}$
From AA to A	14.0	17.3	30.5	5.8	0.4	3.0	4.1	10.8	11.0	18.7	0
A - B	18.8	29.3	12.9	7.7	6.3	7.6	4.5	4.9	5.6	14.0	3.2
B - C	17.6	27.2	11.7	6.5	6.8	7.5	9.8	8.5	2.4	21.0	0
AA - B	30.2	41.5	39.5	13.0	6.7	10.4	8.4	15.2	16.0	30.1	3.2

Data for 146 Female Progeny

Changes in Grade	Live Weight	Breast Meat Weight	Breast Meat % of Live Weight	Shank Length	Keel Length	Body Depth	Breast Depth	Breast Width	Breast Index	Observed Cross-section Breast Area	$\sqrt[3]{\frac{\text{Shank length}}{\text{Body Weight}}}$
From AA to A	8.8	11.4	2.9	3.2	4.3	4.2	8.9	8.5	1.1	17.6	0
A - B	15.7	20.6	5.8	5.9	6.2	6.0	4.1	6.5	4.3	12.4	1.1
B - C	24.0	33.7	12.7	8.4	10.7	14.2	10.8	8.5	3.4	22.7	+1.1
AA - B	23.2	29.7	8.5	8.9	10.3	9.9	12.6	14.4	5.4	27.8	1.1

TABLE VI

Order of Relative Value of Correlation Ratios
Between Live Weight Breast Meat, Body Measurements and
Grade in Males and Females, Respectively

110 Males		146 Females	
Measurement *	Correlation Ratio	Measurement *	Correlation Ratio
Observed cross section breast area	0.87	Observed cross section breast area	.83
Breast meat	.80	Breast width	.76
Live weight	.74	Breast meat	.74
Breast width	.63	Live weight	.73
Body depth	.56	Body depth	.67
Shank length	.53	Keel length	.62
Breast depth	.51	Shank length	.58
Keel length	.50	Breast depth	.57
Breast index	.49	Breast index	.37
$\sqrt[3]{\frac{\text{Shank length}}{\text{Body weight}}}$	-.08	$\sqrt[3]{\frac{\text{Shank length}}{\text{Body weight}}}$	.05

* All measurements are correlated with market grade.

in the U. S. Grade #1, and the present U. S. Grade #2, as comparable to what formerly was U. S. Grade C, the percentage decreases in size of the mean values for each sex and body measurement from the AA to the B grade are also shown in Table V. In the males, the percentage decrease from AA grade to B grade was greater than the percentage decrease from B grade to C grade for live weight, breast meat, amount of breast meat as a percentage of live weight, breast index and observed cross-section breast area, while in the females, the percentage decrease from AA grade to B grade was less than the percentage decrease from B grade to C grade for live weight, amount of breast meat, breast meat as a percentage of live weight, keel length, and body depth.

Even though the percentage decreases shown in Table V vary from grade to grade, the trend of change is in the same direction and the magnitude of the percentage change between the different grades is similar for each respective observation such as live weight, breast meat, and each body measurement. These observations are of practical value to those who grade and package broilers and also to distributors and consumers.

The percentage of AA and also A grade birds was higher in the females than in the males but the live body weight and the amount of meat on the breast were greater in the males than the females in these two grades. The breast meat as a percentage of live body weight was greater in the males than the females in the AA grade, but slightly smaller than the females in each of the other three grades. Except for the depth of breast in the AA grade, all of the body measurements under consideration were larger in the males than in the females in each of the four grades. These observations should be of some value to consumers because they indicate that even though the carcass of the female appears to lend itself toward a higher market grade than the male, the male carcass is usually larger in size and tends to carry more meat on the breast.

The relationship between grade and each body measurement did not appear to be the same as it was between the amount of breast meat and each body measurement in these data. The observed cross-section breast area gave a higher correlation ratio with grade in both males and females than any other measurement. The method used to determine the observed cross-section breast area, which in this study is really a measurement of roundness or fullness of breast, is very similar to that employed by Bird (1943), Darrow and Morgan (1944), and the results secured in this study agree with those which they obtained.

The amount of breast meat and live weight as related to grade also gave good correlation ratios.

The correlation ratios between grade and breast meat and between grade and live body weight were nearly the same in value, particularly in the females. This is to be expected, since the correlation value between live weight and breast meat was very high. All flesh measurements gave a higher correlation ratio with grade than the bone measurements. However, as related to grade, the roundness of breast as indicated by observed cross-section breast area appeared to be the best single criterion of market grade. (See Figure 24)

No positive relationship was found to exist between grade and shank length - body weight ratio. This agrees with the observations made by Jaap (1938) and Dolecek, Wilson, and Poley (1941).

The correlation ratio between grade and breast meat, live body weight, and breast index, respectively, was higher in the males than in the females, while the correlation ratio between grade and breast width, body depth, keel length, shank length and breast depth, respectively, was higher in the females than in the males. The order of the relative value of the correlation ratios between live weight, breast meat, body measurements, and grade in males and females, respectively, is shown in Table VI.

The mean body measurements and their relationship to the amount of meat on the breast, and to the grade of carcass reported in this investigation should be of interest and value to consumers and those engaged in all segments of the industry. They should enable breeders and hatcherymen to produce chickens for meat purposes more efficiently and profitably, and the meat-type chickens which they produce should be more uniform in size and shape and satisfying to consumers. Breeders and hatcherymen, however, all are confronted with the problem of deciding which of the meat production characteristics in their stock need to be improved and the method by which this improvement can be brought about.

Three types of selections are used by breeders. They are known as (1) the tandem, or one-character-at-a-time method, (2) the total-score or index method, and (3) the independent-culling method.

In using the tandem method the breeder selects for one character or trait at a time until that character or trait is improved, then he selects for a second, etc. until each has been improved to the desirable level. The total-score method is selecting for all characters simultaneously by using an index of net merit, based on the degree to which the individual is inferior or superior in each of numerous desirable factors. In the third, or independent-culling method, definite culling levels are established for each character and all individuals below that level are culled or discarded, regardless of the superiority or inferiority of their other characters.

The most effective method is selecting for all characters simultaneously, or for a total score. The least effective is the tandem method or selecting for one character at a time.

Hazel and Lush (1942) have made a theoretical comparison of selecting by each of these three methods. They found that selecting for a total-score based on any number (N) of equally important unrelated traits to be equivalent to the square root of that number ($\sqrt{N}$) times as efficient as selecting for one trait at a time. However, the progress made in any one trait by the total-score method is only $\frac{1}{\sqrt{N}}$ times as much as if selection were directed at that trait alone.

The method of independent culling to definite levels is approximately intermediate in efficiency between the other two. Progress by each method, of course, depends upon the degree of selection. The method of independent culling levels has one practical advantage over the total-score method in that birds may be culled for each trait whenever that trait becomes evident without waiting until all traits can be measured. If independent culling levels are established for several traits, culling too drastically for one trait limits the amount of selection which can be practiced for others. A culling level set too high for a trait which is low in heritability or of small economic importance automatically lowers the intensity of selection for other traits.

It is suggested, therefore, that the total-score or index method, including all of the body observations in this study which were found to be highly correlated with the amount of meat on the breast and also those with carcass grade, such as live body weight, roundness and fullness of breast as measured by observed cross-section breast area, shank length, and body depth, might be used by breeders and hatcherymen to produce more desirable meat-type chickens.

Live Weight and Breast Meat Indices in Purebred and Crossbred Progeny

The mean live weights and mean breast widths are given in Table VII for 720 twelve-week old purebred and crossbred progeny. Fifty-six of these progeny were produced from either purebred Cornish, purebred New Hampshire,

TABLE VII

Mean Live Weight and Breast Width for 720 Twelve-week Old Purebred and Crossbred Progeny

Mating		Progeny		Live Weight	Breast Width
Male	Female	Male	Female	Mean and S.E.	Mean and S.E.
				(gms.)	(cm.)
Cornish	x Cornish	10	7	598.8 ± 45.95	4.5 ± 0.20
New Hampshire	x New Hampshire	12	6	1007.0 ± 37.44	4.4 ± 0.10
Cornish	x New Hampshire	47	57	1141.7 ± 27.43	4.7 ± 0.03
F1(Cor. x N.H.)	x New Hampshire	74	117	1108.5 ± 15.27	4.6 ± 0.03
Cornish	x F1(Cor. x N.H.)	35	25	929.8 ± 28.82	4.6 ± 0.07
F1(Cor. x N.H.)	x F1(Cor. x N.H.)	12	19	891.1 ± 49.90	4.3 ± 0.11
Cornish	x Cornish	10	7	598.8 ± 45.95	4.5 ± 0.20
Barred Plymouth Rock	x Barred Plymouth Rock	16	21	952.7 ± 29.97	4.1 ± 0.05
Cornish	x Barred Plymouth Rock	38	76	973.5 ± 21.54	4.4 ± 0.03
F1(Cor. x B.P.R.	x Barred Plymouth Rock	36	85	839.6 ± 19.91	4.2 ± 0.04
Cornish	x F1(Cor. x B.P.R.)	-	7	666.1 ± 98.90	4.2 ± 0.17
Barred Plymouth Rock	x New Hampshire	12	8	903.9 ± 47.33	4.1 ± 0.10

or purebred Barred Plymouth Rock matings. The remaining birds were either F1, F2, or backcross progeny from crosses between these three breeds.

In these data the variability is much greater for live body weight than it is for the amount of breast meat; especially is this so in those instances where the number of progeny is small. The purebred New Hampshire 12-week old progeny exceeded the purebred Barred Plymouth Rock progeny in mean live body weight by 54.3 grams and the purebred Cornish progeny by 406.2 grams but the mean breast width of the purebred Cornish progeny was 0.1 of a centimeter wider than the purebred New Hampshire progeny and 0.4 of a centimeter wider than the purebred Barred Plymouth Rock progeny.

The mean live body weights and the mean breast widths were both larger in the progeny of the Cornish males mated to New Hampshire females than they were in the progeny of either the purebred Cornish or purebred New Hampshire matings. The mean body weight of the F2 progeny from matings of these F1 males and females was between that of the progeny from the two purebred parents.

The progeny of the Cornish males mated to Barred Plymouth Rock females likewise had a larger mean live body weight than the progeny from either the purebred Cornish or the purebred Barred Plymouth Rock matings. The mean breast width in the progeny from the Cornish males mated to the Barred Plymouth Rock females was larger than it was in the Barred Plymouth Rock progeny, but not as large as it was in the purebred Cornish progeny.

In the progeny of the Barred Plymouth Rock males mated to New Hampshire females, the live weight was not as large as it was in the progeny from either the purebred Barred Plymouth Rock or the purebred New Hampshire matings.

A good example of heterosis in poultry was exhibited in the results secured in this part of this investigation. The mean live weights of the purebred Cornish progeny were very low. For the F1 progeny of the Cornish males mated to New Hampshire females it was very high but for the F2 progeny representing germ plasm from these two breeds it was again low. The progeny produced from the backcross mating, F1 (Cornish x N.H.) males mated to New Hampshire females also had a mean live weight that was noticeably larger than the progeny from either of the purebred or other crossbred matings. Few strains and no two breeds have probably ever consistently shown the same degree of accelerated growth. Heterosis is also exhibited in the width of breast, with the wide breast of the Cornish tending to be dominant.

A further analysis of these data indicated that the mean live weight of the Cornish x New Hampshire progeny differed significantly (odds of 1 out of 100) from the mean live weight of the progeny secured from each of the purebred matings and also from the progeny of the Cornish x Barred Plymouth Rock, the Barred Plymouth Rock x New Hampshire, the Cornish x F1 (Cornish x Barred Plymouth Rock) and its reciprocal cross and the F1 (Cornish x New Hampshire) x F1 (Cornish x New Hampshire) matings. The mean live weight of the progeny of the F1 (Cornish x New Hampshire) x New Hampshire mating was also significantly different from the mean live weight of the progeny of each of the other matings listed in Table VII.

The variability of the mean live weights was the smallest in the progeny of the Cornish x New Hampshire, the F1 (Cornish x New Hampshire) x New Hampshire, the Cornish x Barred Plymouth Rocks, and the F1 (Cornish x Barred Plymouth Rocks) x Barred Plymouth Rock matings.

The increased acceleration in growth among the hybrids as compared with the purebreds agrees with results reported by Jaap and Morris (1937), Horlacker and Smith (1938), Harshaw (1938), Maw (1939), and Knox, Quinn, and Godfrey (1942).

Even though the Cornish is a notoriously slow grower and it is also poor in respect to feathering, hatchability, and egg production, the progeny produced in this investigation from mating Barred Plymouth Rock and especially New Hampshire females to Cornish males produced progeny that was larger in size and better fleshed at 12 weeks of age than progeny from purebred Cornish, New Hampshire, Barred Plymouth Rocks or from crosses of Barred Plymouth Rock males and New Hampshire females. (See accompanying figures) It is just possible that strains of Dark Cornish chickens can be developed through further selection and breeding which do not possess the undesirable characteristics mentioned and that germ plasm from this breed can be used to advantage in the future to improve the carcass conformation and market quality of broilers raised for meat purposes.

Table VIII shows the distribution of the 720 twelve-week old purebred and crossbred progeny according to sex and market grade. The grading was better for the crossbred progeny in both males and females than it was in the progeny from either of the purebreds. The purebred New Hampshire progeny appeared to grade better than the purebred Barred Plymouth Rock progeny and the progeny from the Cornish x New Hampshire matings appeared to grade better than the progeny from the Cornish x Barred Plymouth Rock matings.

Males and females were almost equally represented in the progeny from each of the different matings from which the breast meat was removed and weighed. (See Table IX) The mean amount of breast meat removed from the progeny secured from mating Cornish males to New Hampshire females, Cornish males to Barred Plymouth Rock females, F1 (Cornish x New Hampshire) males with New Hampshire females, and F1 (Cornish x Barred Plymouth Rocks) males with Barred Plymouth Rock females exceeded the mean amount of breast meat removed from all the progeny included in this study. (See Table IX)

TABLE VIII

Distribution of 720 Twelve-week Old Purebred and Crossbred Progeny According to Sex and Market Grade

Mating		Grading of Males					Grading of Females				
Males	Females	AA	A	B	C	R	AA	A	B	C	R
Cornish	x Cornish	2	1	2	4	1	-	-	3	4	-
New Hampshire	x New Hampshire	-	1	5	6	-	-	1	3	2	-
Cornish	x New Hampshire	17	16	12	2	-	23	24	9	1	-
Fl(Cor. x N.H.)	x New Hampshire	16	22	20	13	3	23	41	40	13	-
Cornish	x Fl(Cor. x N.H.)	4	10	11	8	2	6	6	5	7	1
Fl(Cor. x N.H.	x Fl(Cor. x N.H.)	2	2	2	5	1	1	7	7	2	2
Cornish	x Cornish	2	-	2	4	1	-	-	3	4	-
Barred Plymouth Rock	x Barred Plymouth Rock	-	2	6	7	1	1	1	12	7	-
Cornish	x Barred Plymouth Rock	6	16	12	3	2	10	36	22	6	1
Fl(Cor. x B.P.R.)	x Barred Plymouth Rock	3	6	14	10	3	5	18	30	28	4
Cornish	x Fl(Cor. x B.P.R.)	-	-	-	-	-	-	3	1	2	1
Barred Plymouth Rock	x New Hampshire	-	-	3	6	3	-	2	4	2	-

TABLE IX

Amount of Breast Meat and Breast Meat as a Percentage of Live Weight for 256 Purebred and Crossbred Progeny

Mating		Progeny		Breast Meat	
Male	Fmmale	Male	Female	Mean & S.E. (gms.)	Percent of Live Weight
Cornish	x Cornish	5	7	62.4 ± 6.70	9.90
New Hampshire	x New Hampshire	6	5	86.9 ± 4.81	9.14
Cornish	x New Hampshire	11	14	144.2 ± 5.84	9.87
F1(Cor. x N.H.)	x New Hampshire	9	13	123.8 ± 5.12	9.89
Cornish	x F1 (Cor. x N.H.)	14	11	97.9 ± 7.03	9.69
F1(Cor. x N.H.)	x F1 (Cor. x N.H.)	6	11	95.4 ± 9.31	9.89
Cornish	x Cornish	5	7	62.4 ± 6.70	9.90
Barred Plymouth Rock	x Barred Plymouth Rock	6	7	99.2 ± 5.81	9.89
Cornish	x Barred Plymouth Rock	11	26	116.8 ± 5.42	9.99
F1 (Cor. x B.P.R.)	x Barred Plymouth Rock	6	8	106.6 ± 7.29	9.98
Cornish	x F1 (Cor. x B.P.R.)	-	7	74.8 ±16.74	9.88
Barred Plymouth Rock	x New Hampshire	6	6	76.5 ± 8.06	9.91

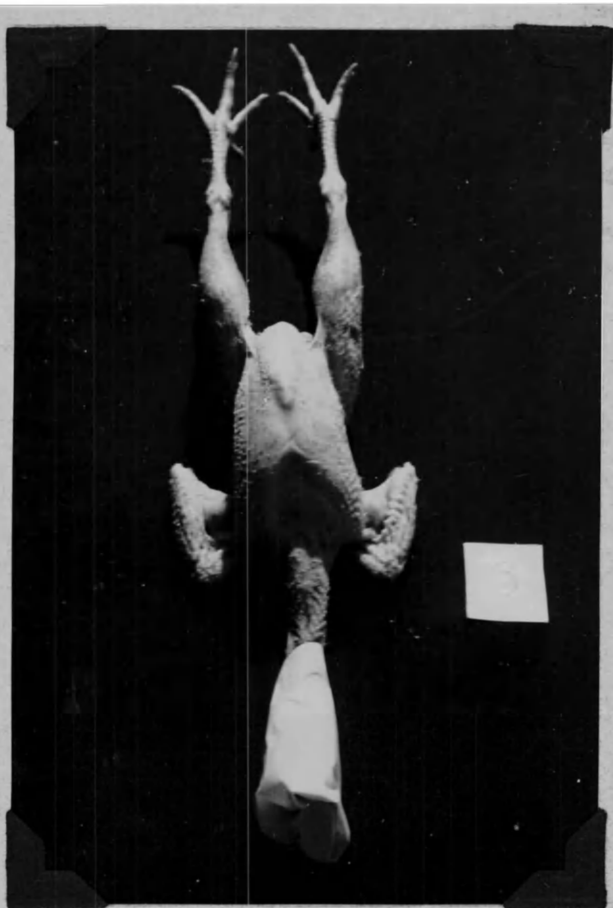


Figure 12. Progeny of Purebred Cornish

Figure 14. Progeny of Cornish x New Hampshire

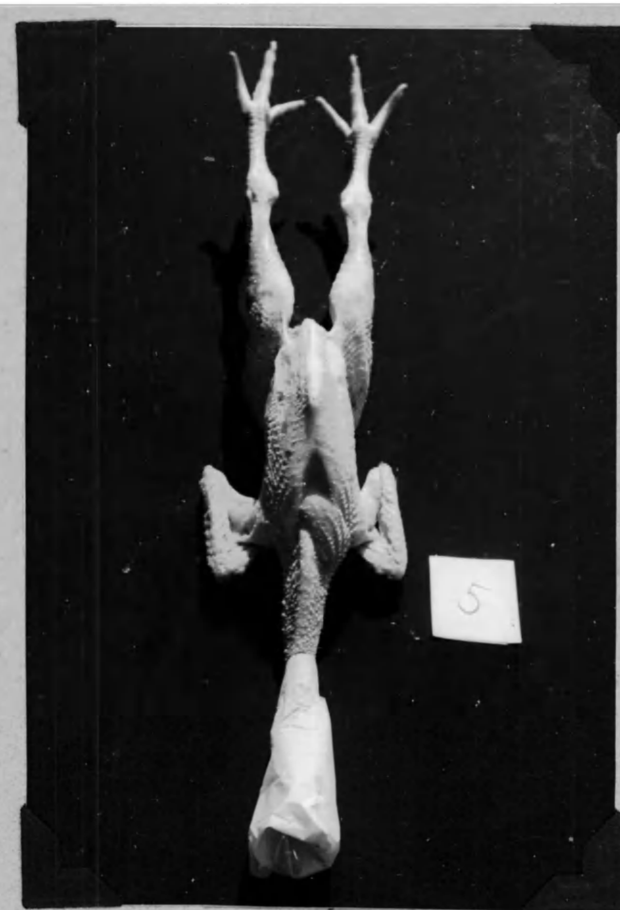


Figure 13. Progeny of Purebred New Hampshire

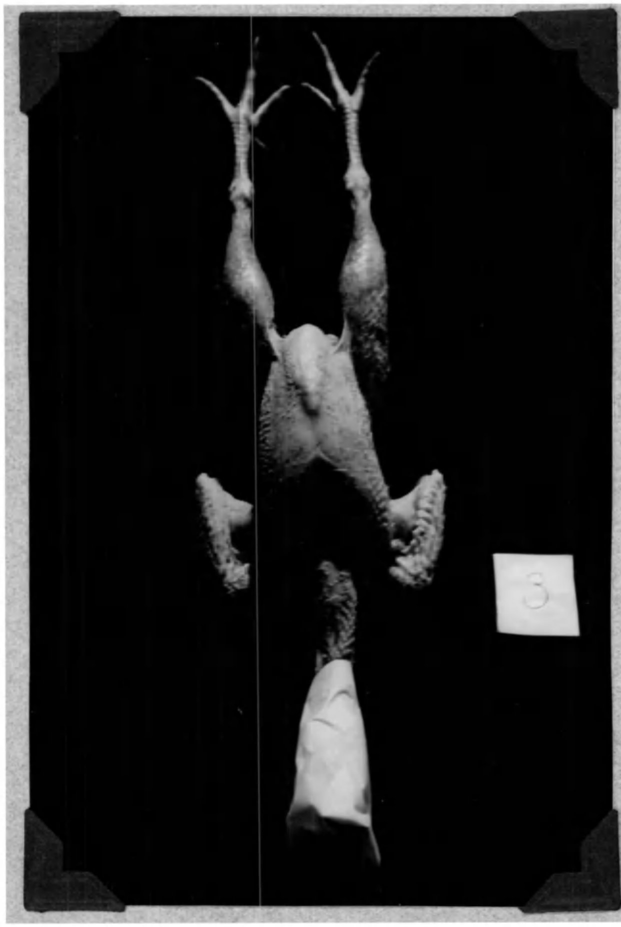


Figure 15. Progeny of Purebred Cornish

Figure 17. Progeny of Cornish x Barred Plymouth Rock

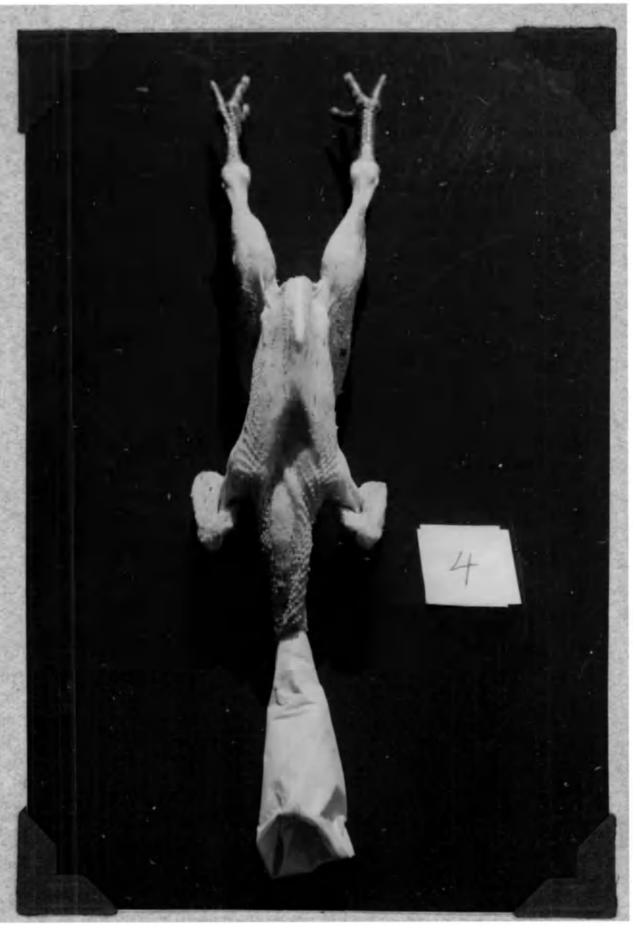


Figure 16. Progeny of Purebred Barred Plymouth Rock

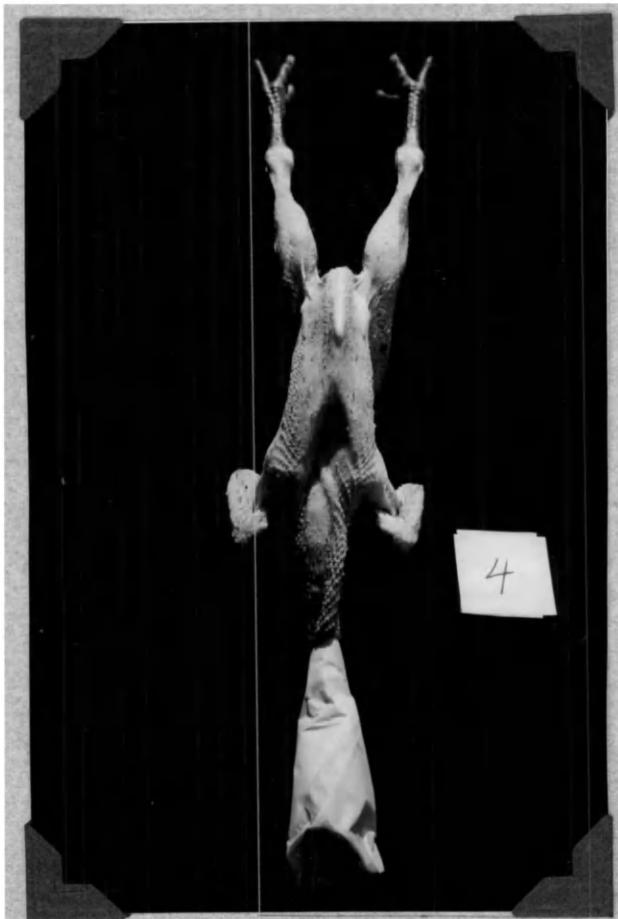


Figure 18. Progeny of Purebred Barred Plymouth Rocks

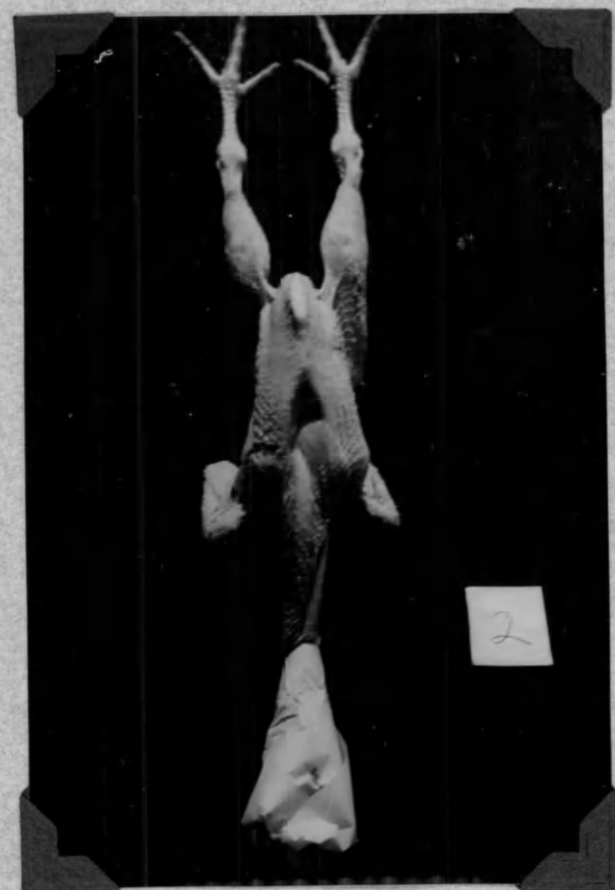


Figure 20. Progeny of Barred Plymouth Rock x New Hampshire

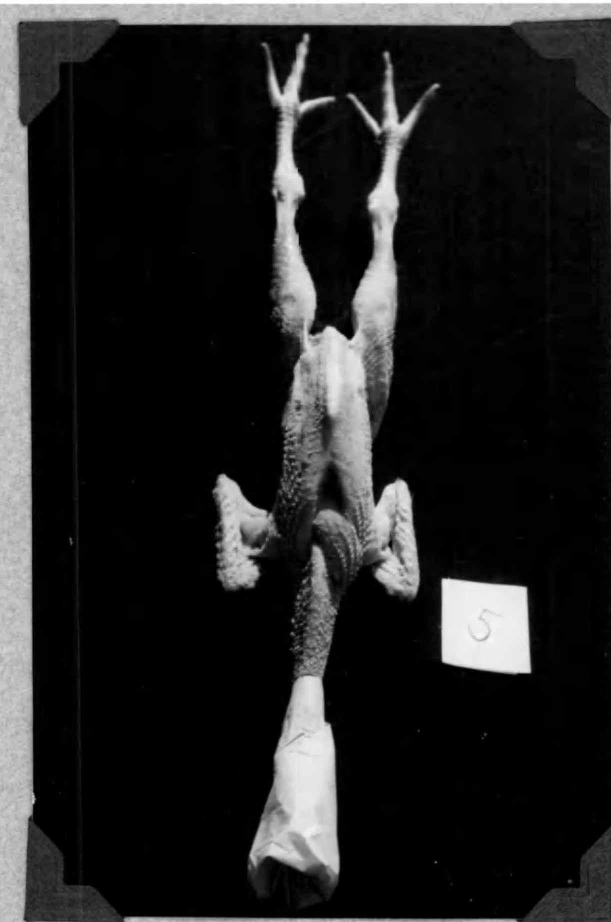


Figure 19. Progeny of Purebred New Hampshire

Figure 21. Progeny of Purebred Cornish

Figure 22. Progeny of Purebred New Hampshire

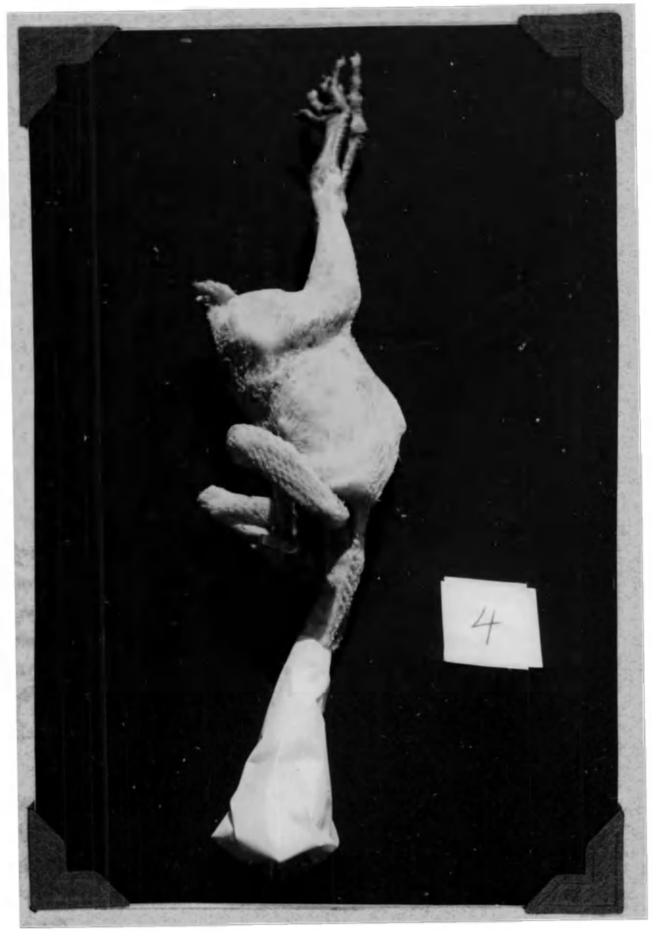


Figure 23. Progeny of Purebred Barred Plymouth Rock

A further analysis of the data in Table IX indicates that there was a significant difference between the mean amount of meat removed from the breast of the offspring from the Cornish x New Hampshire matings and that removed from the same area on the progeny from each of the other matings reported in this table.

The amount of breast meat as a percent of live weight was slightly greater in the progeny of the purebred Cornish, the Cornish x Barred Plymouth Rock, and the F1 (Cornish x Barred Plymouth Rock) x Barred Plymouth Rock matings than it was in the progeny of the other matings reported in Table IX. These percentages show once more that a close relationship exists between the amount of meat on the breast and the live body weight of these progeny.

The distribution according to sex and grade of the purebred and crossbred progeny from which the breast meat was removed and weighed is given in Table X. This distribution is very similar to that shown for all progeny in Table VIII. Here again the grading was better for the crossbred progeny for both males and females than it was for the progeny from either of the purebred matings.

The Relation of the Mean Observed Cross-section Breast Area and Breast Width to Grade

The grade of each sex and size of bird marketed is determined more by the roundness, fullness, and width of the breast than by any other characteristic of the carcass. This is because chickens are exhibited in the market place with the breast up and because the meat on this part of the carcass is light-colored and higher priced.

TABLE X

Distribution, According to Sex and Grade, of Purebred and Crossbred Progeny from which Breast Meat was Removed

Mating		Grading of Males					Grading of Females				
Male	Female	AA	A	B	C	R	AA	A	B	C	R
Cornish	x Cornish	-	1	2	2	-	-	-	3	4	-
New Hampshire	x New Hampshire	-	-	3	3	-	-	1	2	2	-
Cornish	x New Hampshire	5	5	1	-	-	7	7	-	-	-
F1 (Cor. x N.H.)	x New Hampshire	1	4	3	1	-	6	7	-	-	-
Cornish	x F1 (Cor. x N.H.)	1	4	7	2	1	-	3	3	4	-
F1 (Cor. x N.H.)	x F1 (Cor. x N.H.)	1	1	2	2	-	-	3	5	2	1
Cornish	x Cornish	-	1	2	2	-	-	-	3	4	-
Barred Plymouth Rocks	x Barred Plymouth Rocks	-	-	3	3	-	-	1	4	2	-
Cornish	x Barred Plymouth Rocks	1	7	1	2	-	6	9	10	1	-
F1 (Cor. x B.P.R.)	x Barred Plymouth Rocks	-	1	4	1	-	2	4	2	-	-
Cornish	x F1 (Cor. x B.P.R.)	-	-	-	-	-	-	3	1	2	1
Barred Plymouth Rocks	x New Hampshire	-	-	-	4	2	-	2	3	1	-

The data in Table XI are presented to show that:

1. There was a positive relationship between the observed cross-section breast area and grade in these progenies.
2. That purebred Cornish progeny had the largest mean observed cross-section breast area in the AA grade.
3. The mean observed cross-section breast area of the C grade progeny from the purebred and crossbred matings was only about half as large as it was for the AA grade progeny.
4. Progeny secured from the Cornish x New Hampshire matings possessed a slightly larger observed cross-section breast area in all the grades than the progeny secured from the Cornish x Barred Plymouth Rock matings.

Differences in the mean observed cross-section breast area by grades are shown graphically in Figure 24 for the offspring for comparable crossbred matings represented by the largest number of progeny.

Even though broilers with deep, narrow breasts may carry as much or more meat on the breast than broad, shallow-breasted birds, the latter type stands a better chance of being placed in the highest market grade.

The width of breast in chickens and turkeys has been measured at different points above the keel, by such workers as Dolecek, Wilson and Poley (1941), Lerner (1937), Bird (1943), Jaap and Penquite (1938) and Asmundson (1944). While the results obtained were not the same, each of these workers appreciated the fact that the market grade of all sizes of poultry is affected by this particular measurement.

Because of the size variations which occur in poultry, it was felt that some anatomical point or points on the bird's body should be used to determine the width and depth of breast. It was the author's opinion that

TABLE XI

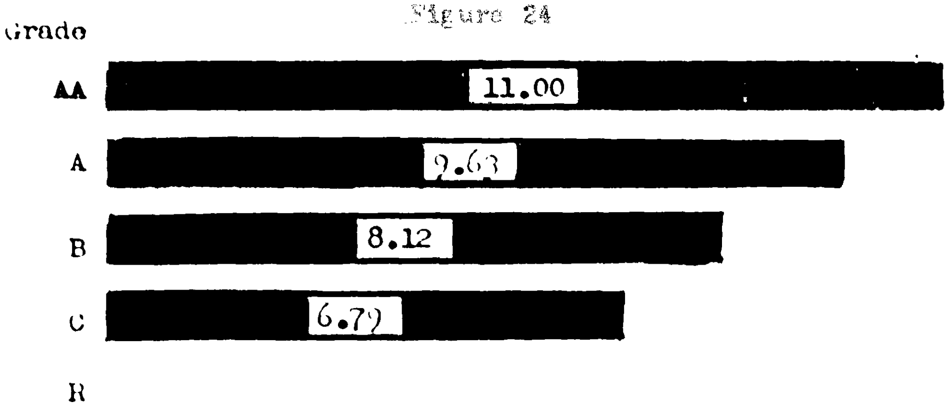
Mean Observed Cross-section Breast Area by Grade for all Purebred and Crossbred Progeny Raised

Mating		AA		A		B		C		R	
Male	Female	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Cornish	x Cornish	2	12.40	1	9.56	5	7.50	8	5.70	1	2.75
New Hampshire	x New Hampshire	-	-	2	10.22	8	8.42	8	6.53	-	-
Cornish	x New Hampshire	40	11.00	40	9.63	21	8.12	3	6.79	-	-
F1 (Cor. x N.H.)	x New Hampshire	39	11.87	63	9.87	60	8.52	26	6.97	3	4.10
Cornish	x F1 (Cor. x N.H.)	10	11.57	16	9.36	16	8.06	15	6.60	3	4.67
F1 (Cor. x N.H.)	x F1 (Cor. x N.H.)	3	11.66	9	9.91	9	8.24	7	6.41	3	4.12
Cornish	x Cornish	2	12.40	1	9.56	5	7.50	8	5.70	1	2.75
Barred Plymouth Rocks	x Barred Plymouth Rocks	1	11.19	3	9.61	18	8.67	14	6.60	1	7.44
Cornish	x Barred Plymouth Rocks	16	10.81	52	9.51	34	8.06	9	6.19	3	4.09
F1 (Cor. x B.P.R.)	x Barred Plymouth Rocks	9	11.38	24	9.49	44	8.20	38	6.48	7	4.42
Cornish	x F1 (Cor. x B.P.R.)	-	-	3	7.75	1	8.43	2	6.46	1	4.56
Barred Plymouth Rocks	x New Hampshire	-	-	2	10.41	7	9.03	8	6.61	3	4.84

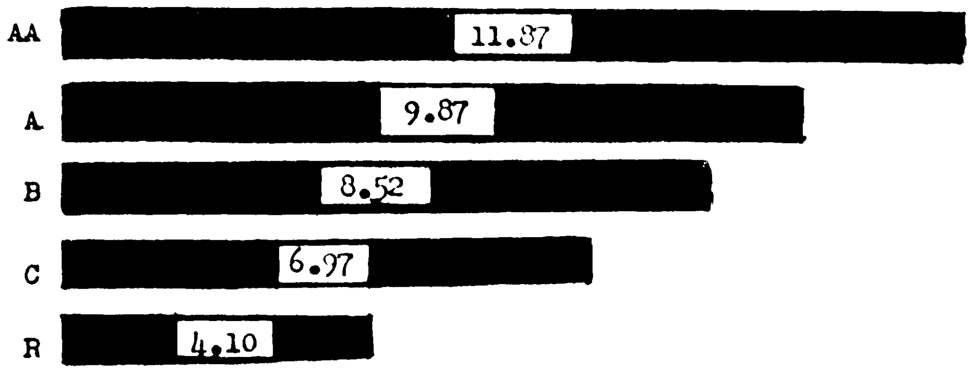
OBSERVED CROSS SECTION AREA OF BREAST BY GRADES

SQUARE CENTIMETERS

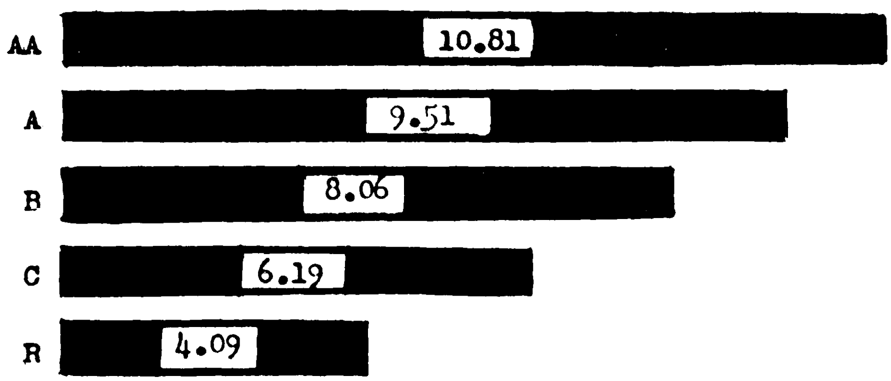
Figure 24



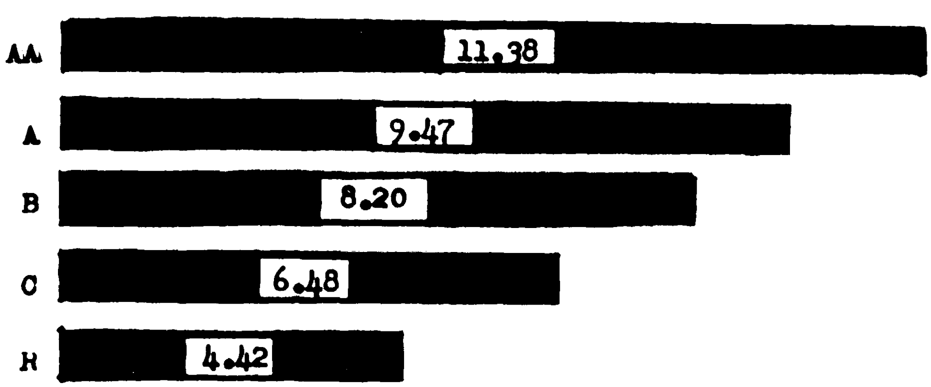
Cornish x New Hampshire Progeny



F_1 (Cor. x N.H.) x New Hampshire Progeny



Cornish x Barred Rock Progeny



F_1 (Cor. x B.R.) x Barred Rock Progeny that the lateral caudal process on each side of the sternum would adequately fulfill this requirement.

The data given in Table XII, and presented in Figure 25, indicate that width of breast was a fairly good index of market grade in the progeny of the crossbred as well as the purebred matings. The distinction between the grades, however, were not as marked as they were for the observed cross-section area, which was also affected to some extent by this measurement. This agrees with the correlation ratios already discussed and presented in Table IV.

The mean width of breast for the broilers in the AA grade was highest for the purebred Cornish, followed by the Cornish x F1 (Cornish x New Hampshire) and the F1 (Cornish x New Hampshire) x F1 (Cornish x New Hampshire) progeny in the order named.

The information in Table XIII indicates that 38.46 percent of the progeny of the F1 Cornish x New Hampshire mating as compared with only 14.04 percent of the progeny from the F1 Cornish X Barred Plymouth Rock mating was placed in the AA grade. It also shows that the grading was not as good in the backcross as in the first F1 progeny. Most of the rejects came from matings where the Barred Plymouth Rock female was the parent.

The absolute number of males and females of each grade in the F1 and backcross progeny is shown in Table XIV. A larger percent of the female than the male progeny from each of the F1 and backcross matings was placed in two top grades. A larger number of the male and also the female progeny where the New Hampshire rather than the Barred Plymouth Rock was used as the female parent was also placed in the AA and A grades.

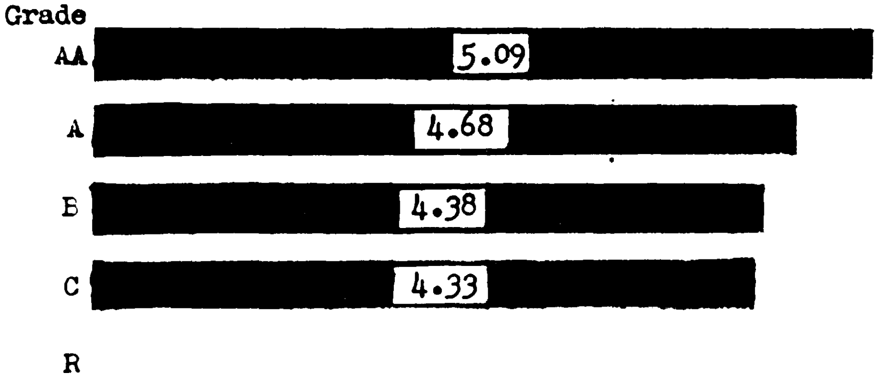
TABLE XII

Mean Breast Width by Grade for all Purebred and Crossbred Progeny Raised

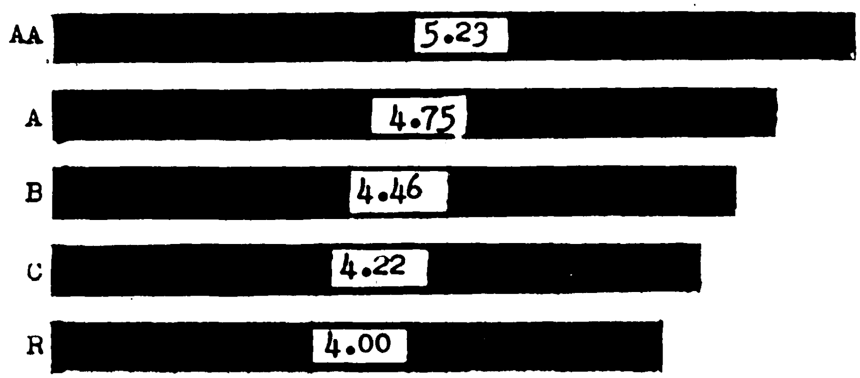
Mating		AA		A		B		C		R	
Male	Female	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Cornish	x Cornish	2	6.15	1	5.70	5	4.72	8	4.01	1	3.20
New Hampshire	x New Hampshire	-	-	2	5.00	8	4.50	8	4.28	-	-
Cornish	x New Hampshire	40	5.09	40	4.68	21	4.38	3	4.33	-	-
Fl (Cor. x N.H.)	x New Hampshire	39	5.23	63	4.75	60	4.46	26	4.22	3	4.00
Cornish	x Fl (Cor. x N.H.)	10	5.58	16	4.86	16	4.45	15	4.17	3	3.57
Fl (Cor. x N.H.)	x Fl (Cor. x N.H.)	3	5.37	9	4.79	9	4.42	7	3.83	3	3.40
Cornish	x Cornish	2	6.15	1	5.70	5	4.72	8	4.01	1	3.20
Barred Plymouth Rocks	x Barred Plymouth Rocks	1	5.00	3	4.53	18	4.24	14	3.86	1	4.70
Cornish	x Barred Plymouth Rocks	16	5.01	52	4.55	34	4.21	9	3.83	3	3.20
Fl (Cor. x B.P.R.)	x Barred Plymouth Rocks	8	5.05	24	4.60	44	4.28	38	3.86	7	3.34
Cornish	x Fl (Cor. x B.P.R.)	-	-	3	4.50	1	4.40	2	4.00	1	3.50
Barred Plymouth Rocks	x New Hampshire	-	-	2	4.55	7	4.81	8	4.00	3	3.47

WIDTH OF BREAST BY GRADES - CENTIMETERS

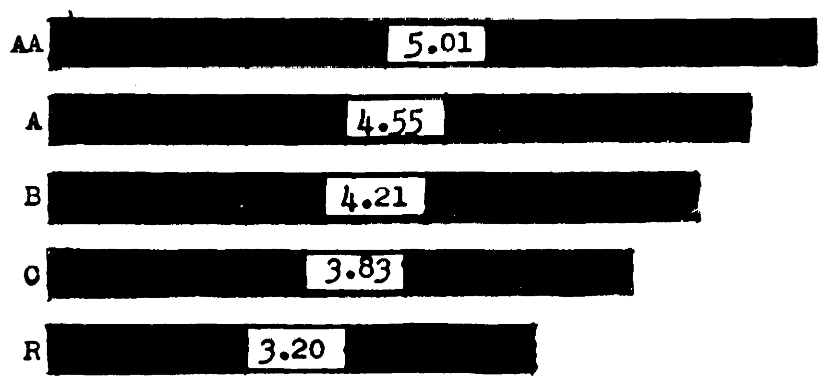
Figure 25



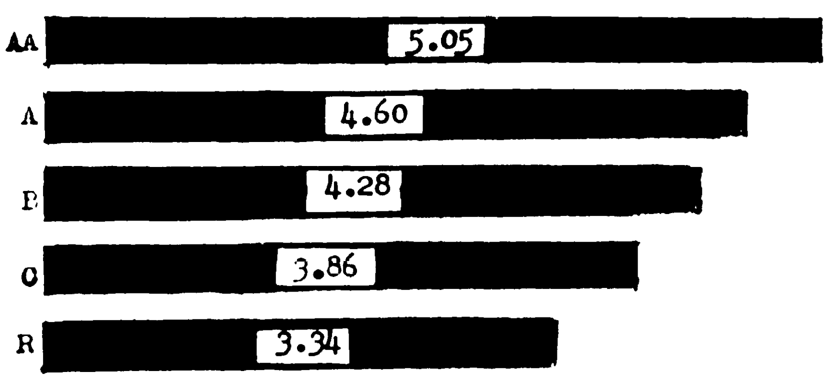
Cornish x New Hampshire Progeny



F_1 (Cor. x N.H.) x New Hampshire Progeny



Cornish x Barred Rock Progeny



F_1 (Cor. x B.R.) x Barred Rock Progeny

TABLE XIII

Percent of F1 and Backcross Progeny by Grades

Mating		Total					
Male	Female	Progeny	AA	A	B	C	R
Cornish	x New Hampshire	104	38.46	38.46	20.19	2.88	--
F1 (Cor. x N.H.)	x New Hampshire	191	20.42	32.98	31.41	13.61	1.57
Cornish	x Barred Plymouth Rock	114	14.04	45.61	29.82	7.89	2.63
F1 (Cor. x B.P.R.)	x Barred Plymouth Rock	121	6.61	19.83	36.36	31.40	5.79

TABLE XIV

Absolute Number, by Sexes, of Each Grade
in F1 and Backcross Progeny

Mating		Total	Males					Females				
Male	Female	Number	AA	A	B	C	R	AA	A	B	C	R
Cornish	x New Hampshire	104	17	16	12	2	-	23	24	9	1	-
F1 (Cor. x N.H.)	x New Hampshire	191	16	22	20	13	3	23	41	40	13	-
Cornish	x Barred Plymouth Rock	114	6	16	11	3	2	10	36	23	6	1
F1 (Cor. x B.P.R.)	x Barred Plymouth Rock	121	3	6	14	10	2	5	18	30	28	4

Comparison of Progeny from Individual Matings

Tables XV and XVI contain interesting information on male and female progeny secured from individual matings. Data is reported in these tables for the progeny from four different New Hampshire and four different Barred Plymouth Rock females mated to the same Cornish male.

Except for the mean breast width in the progeny of dams #596 and #598 and the amount of breast meat in the progeny of dams #591 and #598, each of the mean values given in these tables for live body weight, breast width, breast meat, and breast meat as a percent of live body weight, are higher than they are for the progeny secured from the purebred Cornish, purebred New Hampshire, purebred Barred Plymouth Rock, and from these two respective crossbred matings. (See Tables VII and IX) The mean values given for the progeny of the four New Hampshire females were higher for each of these different measurements, except breast meat as a percent of live weight, than they were for the progeny of the four Barred Plymouth Rock females. The same relationship was true so far as market grade was concerned.

The difference between the mean amount of breast meat in the progeny of New Hampshire female #553 and in the progeny of Barred Plymouth Rock female #596, mated to the same Cornish male, was significant.

These data indicate that the individual birds used in the original matings differed genetically in their ability to transmit body conformation and fleshing ability and that progress beyond that reported in this investigation might be made through selective breeding.

TABLE XV

Mean Live Weights, Body Measurements, and Grades of Progeny from Individual Family Matings

Matings		Parents		Progeny		Live Weights		Breast Width		Grades				
Male	Female	Male	Female	Male	Female	Mean & S.E.		Mean & S.E.		AA	A	B	C	R
						(gms.)		(cm.)						
Cornish	x New Hampshire	#449	#253	6	7	1331	51.06	4.7	0.09	7	6	-	-	-
Cornish	x New Hampshire	449	551	10	13	1084	44.18	4.7	0.08	4	13	6	-	-
Cornish	x New Hampshire	449	553	8	14	1243	22.72	4.8	0.08	12	9	-	1	-
Cornish	x New Hampshire	449	555	7	6	1273	37.47	4.9	0.11	7	4	2	-	-
Cornish	x Barred Plymouth Rock	449	357	5	19	980	58.42	4.4	0.10	4	11	6	2	1
Cornish	x Barred Plymouth Rock	449	591	4	10	973	42.36	4.4	0.10	1	9	4	-	-
Cornish	x Barred Plymouth Rock	449	596	10	14	977	44.06	4.3	0.09	1	13	5	4	1
Cornish	x Barred Plymouth Rock	449	598	10	13	982	43.77	4.3	0.07	3	10	9	1	-

TABLE XVI

Mean Amount of Breast Meat, Breast Meat as a Percent of Live Weight and Grade of Progeny from Individual Family Matings

Matings		Parents		Progeny		Breast Meat		Grades				
Male	Female	Male	Female	Male	Female	Mean and S.E. (gms.)	% of Live Weight	AA	A	B	C	R
Cornish x	New Hampshire	#449	#253	2	3	146 ± 14.70	11.33	2	3	-	-	-
Cornish x	New Hampshire	449	551	-	1	154 ± -	13.04	-	1	-	-	-
Cornish x	New Hampshire	449	553	3	7	154 ± 8.45	11.56	8	2	-	-	-
Cornish x	New Hampshire	449	555	2	3	145 ± 5.65	11.75	2	3	-	-	-
Cornish x	Barred Plymouth Rock	449	357	-	5	123 ± 17.64	12.12	1	1	3	-	-
Cornish x	Barred Plymouth Rock	449	591	1	2	112 ± 9.08	11.58	1	1	1	-	-
Cornish x	Barred Plymouth Rock	449	596	6	5	122 ± 7.09	11.47	1	6	2	1	-
Cornish x	Barred Plymouth Rock	449	598	-	3	109 ± 9.79	12.05	-	2	1	-	-

SUMMARY

Data were collected on 720 twelve-week old purebred and crossbred progeny. The breast meat was removed from 110 males and 146 females and coefficients of correlation for each sex were calculated between the amount of breast meat and each of the body measurements taken. All of the progeny were graded subjectively according to the Tentative U. S. Standards and Grades for Live Poultry and correlation ratios between market grades and each of the body measurements were determined for males and females separately by Carl Pearson's Method.

The mean values of live weight, breast meat, breast width, and the observed cross-section breast area were determined for the progeny secured from each of the purebred and crossbred matings. The mean values for the male and female progeny from each of these matings were compared to determine significant differences. A total score or index method, including all of the body measurements which were found to be correlated with the amount of breast meat and market grade, was suggested for use by breeders and hatcherymen who are interested in the production and marketing of more efficient and more desirable meat-type chickens.

Data were obtained and comparisons made on live weight, mean amount of breast meat, breast meat as a percent of live weight, and market grade for progeny secured from four different New Hampshire and four different Barred Plymouth Rock females mated to the same Cornish sire.

In brief, information was obtained for these 12-week old purebred and crossbred progeny concerning:

1. Factors that affect the quantity of breast meat on the carcass.
2. The relationship between the quantity of meat and market grade.

3. Body measurements in relation to quantity of breast meat and market grade.

4. The effects of heterosis on rate of growhh to 12 weeks of age.

5. Genetic differences with respect to ability to transmit body conformation and fleshing ability.

CONCLUSIONS

An analysis of the data obtained in this investigation appears to justify the following conclusions.

1. Live body weight is the best criterion of the quantity of breast meat on chickens at 12 weeks of age, both purebred and crossbred.

2. The difference in the mean live weight between males and females is significant.

3. A high ratio exists between shank length and cube root of body weight in both males and females.

4. The shank length-body weight ratio is not a good index of the amount of breast meat.

5. Breast meat as a percent of live weight is higher in females than in males.

6. Breast index did not prove to be a good measure of breast meat or of market grade.

7. Observed cross-section breast area is the best criterion of market grade.

8. The correlation ratios are higher between flesh measurements and grade than between long bone measurements and grade.

9. The fastest growing chickens tended to grade the highest.

10. Females tend to grade higher than males, but in the AA grade birds, breast meat as a percent of live weight is higher in males than in females.

11. The mean live body weight is significantly larger in the progeny of the Cornish x New Hampshire mating than in the progeny of each of the following matings: Cornish x Barred Plymouth Rock, Barred Plymouth Rock x New Hampshire, purebred Cornish, purebred Barred Plymouth Rock, and purebred New Hampshire.

12. The variability of live weight is greater in the purebred and F2 progeny than it is in the Cornish x New Hampshire progeny.

13. The amount of breast meat on the carcass of Cornish x New Hampshire progeny is significantly larger than the amount of breast meat on the carcass of the other crossbred and purebred progeny included in this investigation.

14. The breast width of purebred Cornish and Cornish crossbred progeny is larger than the breast width of the other purebred and crossbred progeny included in this study.

15. Progeny from Cornish x New Hampshire matings tend to grade higher than progeny from the other purebred and crossbred matings.

16. In view of the slow rate of growth in the purebred Cornish progeny, the effects of heterosis due to crossbreeding were outstanding.

17. The progenies of different New Hampshire and of different Barred Plymouth Rock females mated to the same Cornish male differ significantly in mean live weight, breast width,

breast meat, market grade, and breast meat as a percent of live weight. This indicates that rate of growth and fleshing ability are inherited.

18. The results secured from this study indicate that there are at least some different genes involved in determining skeletal development on the one hand and fleshing ability on the other hand.

19. This being so, it should be possible by proper selection and mating to develop purebred strains of birds excelling in body conformation combined with an abundance of fleshing that will produce a superior type of market grade of poultry.

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AMOUNT OF BREAST MEAT AND GRADE OF CARCASS IN RELATION TO BODY MEASUREMENTS IN PUREBRED CORNISH, NEW HAMPSHIRES, BARRED PLYMOUTH ROCKS AND THEIR CROSSES

Data were collected showing the amount of breast meat and grade of carcass in relation to body measurements on 720 twelve-week old purebred Cornish, New Hampshires, Barred Plymouth Rocks, and their crosses.

Statistical analysis of the data indicated that the amount of meat on the breast is affected by the rate of growth, breed and sex of the bird. Live body weight was found to be the best criterion of the quantity of breast meat on purebred and crossbred chickens of this age. The amount of meat on the carcass of the Cornish x New Hampshire progeny was significantly greater than the amount of breast meat on the carcass of the other crossbred and purebred progeny. The relative amount of breast meat was greater in the females than in the males.

Size and breed were also observed to have an important effect upon market grade, in that the fastest growing birds and the progeny from the Cornish x New Hampshire matings tended to grade the highest.

The observed cross-section breast area was the best criterion of market grade and the correlation ratios were higher between flesh measurements and grade than between long bone measurements and grade. Of the bone measurements used in this investigation, shank length gave the highest correlation with the total amount of breast meat.

The study indicated that the inheritance of body conformation and fleshing is complex.