EVALUATION OF INDUSTRY BREEDING PROGRAMS
FOR MEAT-TYPE CHICKENS AND TURKEYS
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SUMMARY

This paper traces the brief, though dynamic, history of industry breeding programs for meat-type chickens and turkeys in the context of the market demand-breeding interface. Although the degree of success of specific breeding programs is variable, in general they have contributed largely to the quantum changes that have occurred during the last fifty years in the ages and weights at which chickens and turkeys are marketed. Breeders capitalized on intense selection, development of specialized sire and dam lines and a lack of genotype-environment interactions to develop a hybrid that grows fast and is an excessive consumer of food. Attempts to circumvent the negative aspects of potentially overweight and obese parents have included both genetic and nongenetic procedures. Emphasis in this paper is given to the chicken with the turkey discussed on the basis of similarities and dissimilarities.

INTRODUCTION

Although breeding of chickens has a history of thousands of years, be it for religious, ceremonial, sport, or egg production (24), breeding to provide a nonagricultural population with meat is a 20th century phenomenon (8, 14, 15). The domestication of the turkey, unlike the chicken, does not go back to the Neolithic period. Rather, the turkey is a new world species that has been used for meat production (23), with turkey meat breeding preceding that of chicken meat breeding.

In this paper, we provide a brief history of breeding for poultry meat. Breeding programs are discussed in the context of objectives focusing on demand or need, related genetic and nongenetic factors known at the time, and breeding programs that were used for chickens and turkeys.

CHICKENS

History

Until the 1920's, the production of chickens for meat was a by-product of the table egg industry (8). The next two decades saw increased interest in the development of "dual-purpose" brown-egg breeds where the cockerels were reared for meat and the pullets for egg production. In 1929, the "Hallcross" entered the market. This

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cross, produced by mating Rhode Island Red sires to Barred Plymouth Rock dams, utilized sex-linked loci for plumage color which allowed differentiation between sexes of chicks at hatching. Pullets were raised to produce table eggs and cockerels were raised for meat. Progeny from the reciprocal cross were not sexable by plumage color and were reared for meat. Other breeders quickly followed this breeding program and sex-linked hybrid crosses became extremely popular in the brown-egg market of the Northeastern USA until shortly after World War II.

During this period, some breeders were interested in using New Hampshire chickens for meat production with eggs as the by-product (8). Mass selection for growth and body conformation was used by some breeders while progeny testing was the preferred system of others. Following the end of the war, George Ellis used progeny-testing and selection to produce a white-feathered synthetic that emphasized growth and conformation (8). This synthetic was derived from the Barred Plymouth Rock and New Hampshire breeds. Its white plumage eliminated the dark pinfeather problem that plagued processors.

By the end of World War II, it was generally assumed that if a chicken meat industry was to develop, it had to be unique unto itself and not be a by-product of the brown egg industry. Moreover, there was no future for the dual-purpose chicken. Considerable impetus to this thinking came in 1945 from sponsorship of the "Chicken-of-Tomorrow" program by the Great Atlantic & Pacific Tea Company (8). Specialized meaty lines of Cornish, Wyandotte, Plymouth Rock, and New Hampshire breeds were developed by scores of breeders. The need for a white-feathered broiler for processing quickly eliminated the New Hampshire as a source of breeding stock. Similarly, rose comb varieties disappeared because of the association of rose comb and reduced fertility (4). The demise of pea comb was slower because its association with slightly reduced growth and increased incidence of breast blisters was not dramatic (18).

By 1960, many breeders had disappeared from the scene and white-feathered commercial broilers were produced from specific male and female lines. Meat-type breeding was no longer an art. Breeders employed geneticists who used quantitative and qualitative procedures with intense within-line selection plus crossing to produce a hybrid commercial product. The male lines of choice were of the "Cornish type" noted for their body conformation and dominant white plumage. Dominant white was gradually replacing recessive white in breeding programs. White Rocks became the dam of choice. Heritabilities of about .40 for body weight and conformation plus a positive genetic correlation between them allowed for individual phenotypic selection and short generation intervals. This breeding situation, interfaced with consumer acceptance of poultry meat as a food for other than weekend and holiday meals, provided ready markets for large volume production.

Reduced egg production resulting from negative correlations with body weight contributed to the development during the late
1960's and 1970's of the system of producing a broiler which was a three-way cross that used a hybrid mother to increase egg production. More recently, hybrid sire lines have become popular as breeders attempt to further protect their germ plasm.

It is obvious that chicken meat breeding has had a very dynamic but short history. Attrition among breeders has continued into the 1980's. The few survivors used sound genetic principles, had a willingness to gamble, and had considerable luck. In several cases they became subsidiaries of multinational corporations, suggesting that they were valuable assets and in turn they were provided capital for investment. The rule of the day is to use large populations with intense selection and hybrid vigor. Broilers produced from such programs are available worldwide. In the USA, as elsewhere, changes in broiler performance are a function of genetic and nongenetic factors. Using USA figures, it required about 95 days and 5.6 kg of feed to produce a 1.3 kg broiler in 1935. Twenty-five years later, it was 67 days and 3.8 kg of feed to produce a 1.5 kg broiler (13). Today, a 1.8 kg broiler is produced in 45 days from 3.6 kg of feed. Thus, during the past 50 years demand has changed so that while market weight is about 50% larger, broilers reach this age in half the time on a third less feed.

Breeding programs for poultry meat were based on sound genetic principles (9, 14, 15). Being a "new industry," they had the advantage of having a backlog of diverse germ plasm and basic information on poultry genetics that was waiting to be used. Mass transportation and computer technology contributed to the development of large centralized breeding facilities. Although they capitalized on these factors, poultry meat breeders have returned little to the storehouse of knowledge. They have been users and not producers of science, and the effect of a reduced inventory of information cast a cloud on how future evaluations may rate industry breeding programs.

Growth Rate and Feed Conversion

Primary demand in the poultry meat industry has been for a fast-growing bird that is an efficient converter of foodstuffs to edible product. Due to an antagonistic relationship of rapid growth with high fecundity, poultry breeders came to realize, especially post-World War II, that both could not be incorporated into a single population. Even those who question this negative relationship were aware of the inefficiency of selecting simultaneously (in term of intensity) for two major traits (26, 27). Body weight was easy to measure and responded to mass selection, while fecundity traits such as egg production, were sex-limited, expensive to measure, and showed little response to selection. Moreover, selection for rapid growth meant that broilers reached market weight at younger ages and thus, feed conversion ratios were improved primarily from savings in the feed consumed for maintenance. It has been estimated (20) that a reduction of one day in reaching market weight reduces food consumption per bird by 50 to 60 g. Feed conversion ratios at
market age were approximately 4.3 in 1935, 2.5 in 1960, and 2.0 in 1985. During this period, dramatic changes occurred in husbandry and in poultry nutrition, especially the feeding of high energy diets during the 1950's and disease eradication programs during the 1960's.

Breeding methods involved individual phenotypic selection for body weight at market age with high selection intensities (1 to 5% in males, 5 to 20% in females) and family selection and progeny testing. The latter had little advantage over mass selection because of the high heritability of body weight and lower operational costs and shorter generation intervals associated with mass selection. Correlated responses, while including improved feed efficiency and better conformation, also included increased leg problems, obesity, and lowered reproductive performance. Breeders, while always aware that the main objective in their breeding program had to be a fast-growing broiler, addressed these correlated responses in a variety of ways and with varying degrees of success. For example, breeders were content to capitalize indirectly on improved feed efficiency through broilers reaching market weight at younger ages. They also viewed the increases in feed consumption, where broilers were overeaters in a positive context because the increased feed consumption, in turn, resulted in heavier weights. Gordy (8) relates how increasing body weights of chickens by overconsumption of feed was used in the 1890's by W. G. Anthony who by cramming chickens increased body weights from 1135 to 2270 g in 3 weeks for an average daily gain of 54 g.

To our knowledge, the philosophy of improving feed efficiency through selection for growth existed among all but one breeder through most of the 1970's, when it became obvious that little genetic improvement had occurred in this trait since the late 1960's (2). Accordingly, the 1980's have seen emphasis given to direct selection for improved feed efficiency. Unfortunately, there is a dearth of information, not only on the inheritance of feed efficiency, but also on how to measure the trait. These voids can impede genetic progress for improving this trait.

Processing and Carcass Quality

Rapid changes in consumer demands and in poultry processing techniques during the post-World War II era had major effects on poultry breeders. The early 1950's saw increased mechanization in poultry processing which created a need for a uniform bird with white feathers and few pinfeathers. Uniformity was obtained as a by-product of the crossing procedures discussed earlier. The modes of inheritance of dominant white and early-late feathering were known (10, 12) and those breeders who incorporated these alleles in their flocks were able to adapt within a few generations to this market demand. Pleiotrophic effects of alleles at specific loci on production traits are generally unknown and remain essentially unaddressed by poultry breeders. This lack of information may explain, in part, why broiler chicks are sexed by feather growth rather than color.

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Breeders are also aware of short circuitry of their efforts by nongenetic procedures. For example, marketing demands for white and yellow-skinned birds appeared and disappeared during the 1950's. Breeders could, and some did, provide such birds by the use of alleles which allowed or inhibited deposition of xanthophyll (10, 12). A genetic approach, however, became infeasible because a yellow-skinned bird could be made white-skinned by diet and/or changing the scald temperature during processing. In several cases, those breeders who responded to this demand had no market for a white-skinned broiler.

Difficult challenges for breeders to respond to have been a continued demand for increased breast meat and the recent emphasis on higher processing yields. The difficulties come from two vantage points; the traits are polygenically inherited and, in some cases, require indirect measurements (16) and changing marketing demands from whole bird to cut-up to further processing and recently to deboning (13). Breast information, usually obtained at the time birds were weighed, has been used as a secondary selection criterion. Whether this approach is satisfactory in an era of deboning is unknown. Carcass quality traits have been addressed by selection, emphasizing variability in component parts and yield at various weights and ages (16).

Since the mid-1970's, there has been concern with excessive abdominal fat in broilers. Although fat deposition can be reduced through nongenetic means, the broiler industry has been reluctant to do so because of economics. Since 1980 (22), several laboratories have shown that fat deposition is highly heritable and not too strongly associated with body weight, and that selection against excessive fat deposition can be made either directly (by sib-selection) or indirectly (by individual selection on correlated traits). In addition, improvements in feed efficiency may have spin-off effects with regard to fat deposition. As mentioned previously, until recently the major improvements in feed efficiency were achieved from a reduction in marketing age (17) and from nongenetic factors. Residual genetic variation, however, exists for feed efficiency at fixed weights and ages. Perhaps through direct selection for feed efficiency, which has been emphasized during the 1980's, there will be concomitant reductions in the amount of carcass fat.

Disease Resistance and Response to Vaccines

Production practices for maintaining parent breeding flocks and commercial broilers have changed dramatically during the life of this young industry. Whereas, mortality of 10 to 15% was routine in broiler flocks just a few years ago, today mortality in excess of 5% is uncommon. Since broilers are marketed at younger ages, there is less time for them to be exposed to infectious agents and maternal antibody offers proportionately longer protection. Breeders have made use of maternal antibody protection (6, 7) and since broilers are hybrids, there is also the advantage of heterosis. Regarding breeder flocks, mortality in excess of 1% per month in a population is a cause for concern.
The reduction in mortality of meat-type poultry has come mainly through nongenetic factors (6, 7). Farms with 20,000 breeders or over 200,000 broilers at any one time are not uncommon in many areas of the world. Many of these operations have rigid disease prevention and control programs. Parent breeder flocks and commercial flocks are not maintained on the same premises. Also, the setting for conducting primary breeding differs considerably from that where parent breeder flocks are maintained. All of these items complicate breeding for disease resistance.

The response of poultry breeders to demands for increased resistance to disease and response to vaccination against pathogenic agents has varied. Although there is considerable evidence showing genetic variation for resistance to infectious agents (6, 7), selection programs are difficult to design because resistance to one organism does not necessarily confer resistance to others, measurement is complex because thresholds may be involved, and development of nongenetic solutions may short-circuit the expense of development of resistance for a particular infectious agent into the breeding program. This latter aspect was demonstrated in the 1970's with the development of vaccines for Marek's disease. In contrast, the use of anti-coccidials has been less successful because of natural selection for coccidia resistance to their continual use (3), and because they may have negative effects on feed consumption (5) and processing characteristics (1). Yet, it appears that breeders are ignoring genetic approaches to controlling this problem.

Breeders have been quite successful in responding to the demands to develop routine vaccination programs for maternal antibodies which are passed through the egg to the chick, and the eradication of egg-transmitted pathogens. Successful eradication programs include Salmonella pullorum (prior to 1960) and Mycoplasm synoviae, and Mycoplasma gallisepticum (during the 1960's). Eradication programs have included immunological tests and strict sanitary measurements. Today, breeders are attempting to identify and eliminate leucosis shedders (7). Also, some breeders are testing stocks for blood allosystems, especially for alleles at the major histocompatibility locus which is associated with general disease resistance. It is ironic to note that considerable interest in blood-typing at the breeder level existed during the 1960's and then disappeared from the poultry meat-breeding scene. Perhaps the reason is that breeders attempted to "leap-frog" from basic research to application without conducting feasibility studies. Immunological procedures developed during the 1970's and 1980's, such as the development of monoclonal antibodies, are becoming cost effective for use in poultry breeding programs.

Reproduction

Reproductive problems have long plagued the poultry meat industry. The genetic practices which enable broilers to reach market weight at earlier ages result in large parents that are overconsumers of feed and have low fecundity which is exaggerated.
by their being overweight and obese. Attempts to address this problem have included genetic and nongenetic procedures.

With regard to males, breeders have for decades used independent culling of individuals with poor coordination and leg problems. Otherwise, procedures such as feed restriction have been emphasized to prevent males from becoming overweight and socially castrated. Since the mid to late-1970's, some breeders have initiated screening programs whereby males are tested for semen quality and libido before being placed in primary breeder flocks.

Concerning the female side, certain genetic problems can be compensated for by using a hybrid. Regardless of genetic stock, feed restriction must be imposed and it can be effective only up to the genetic limit. Some consideration might be given to the effect of genetic variation for minimal body weight at sexual maturity (25). More popular has been an interest in using the sex-linked allele for dwarfism in the breeder female. This gene, which reduces body weight of dams by approximately 30-35%, enables dwarf females, when mated to normal males, to produce nondwarf progeny (11). Regardless of the procedure used, there is a reduction in feed cost by having smaller breeder parents.

Progeny testing for egg production and also for the erratic ovulation and defective egg syndrome has become fairly routine since the mid-1970's. Also, the dwarfing allele, in addition to reducing the body weight of the breeder, tends to reduce the incidence of erratic ovulation and defective egg syndrome (21). To date, the drawback of using dwarf dams is that their male offspring appear to be up to 3% lighter in weight than those from normal dams. There is some evidence, however, that continued selection is eliminating this undesirable aspect in the utilization of dwarf dams.

Heterosis

Procedures that utilize heterosis have been important in breeding programs. Heterosis provides not only superiority of the hybrids over their parental populations for single traits, but also allows breeders to respond to demands for superiority in a combination of traits. For traits whose inheritance is essentially additive, the use of specialized sire and dam lines yields an "economic heterosis" by providing a combination of low chick cost with superior growth.

No single breed of chickens combines all the desired qualities for meat production, and selection for these qualities in a single population is inefficient. Although nonadditive genetic variation and genotype-environment interactions for growth-related traits are not large, there is evidence of specific combining ability for growth and for feed efficiency. Dominance variation is important in reproductive traits and hence the use of hybrid dams has advantages other than protection of germ plasm. The result has been that poultry meat breeders developed parental lines for combining qualities in hybrid offspring. Specialized sire and dam
lines have been produced which reduce the cost of broiler chick production. The crossing of two dam lines to utilize hybrid vigor for reproductive traits has been a routine practice for over a quarter of a century. More recently, one has seen the advent of four-way crosses, where a hybrid male is mated to the hybrid dam to produce a four-way cross. The main reason for this mating is the protection of male line germ plasm.

Thus, within-line selection involving individual and family records, coupled with crossing of lines to produce both hybrid male and female parents, has become the rule of the day for the commercial poultry breeder. The exception to this type of a breeding program is where the broiler producer is doing his own breeding and not selling commercial breeding stock. In these cases, the breeding program can be tailored to their specific product. These individuals, of course, have the luxury of not being concerned with the protection of germ plasm that goes into their product.

TURKEYS

The broiler and the turkey industries have comparable needs such as rapid growth, superior feed efficiency, and high processing yield. Turkeys, as broilers, have shown a continuous response to selection for growth rate (heritability approximately .40) and negative correlated responses of reproductive traits (9, 19). In general, breeding programs for turkeys and meat-type chickens are similar. The commercial breeds are produced by crossing specialized sire and dam lines which are continuously selected on the basis of individual and family records. Specific differences, however, exist between turkey breeding and broiler breeding, and they will be discussed in the following paragraphs.

The history of the broiler and turkey industries differ in that the chicken-meat production was initially a by-product of the egg industry, while there has never been a turkey egg industry, i.e., turkeys are raised for meat (23). Intensive breeding of turkeys for growth rate and conformation commenced about 20 years before similar goals were pursued in chickens. As a result, the turkey led the broiler, not only in the emphasis on breast size, but also in reproductive difficulties.

The development of definite turkey breeds in North America started during the second half of the 19th century. Emphasis was aimed more toward appearance in terms of body type and plumage color than for utility traits (23). In Europe, however, turkeys were specifically bred for meat production. In 1927, a breed of turkeys imported to Canada from England was crossed with American breeds to establish the famous Broad Breast Bronze. In the following years, the commercial turkey industry developed, with utility traits replacing the traditional "show" traits in the breeding programs. Beginning in the 1950's, white feathers replaced the bronze plumage with the transition being completed by the late 1960's.
The response of turkeys to intense selection for body weight, and especially for broad meaty breasts, caused mechanical barriers to natural mating which resulted in low fertility. The development of artificial insemination procedures during the 1930's (23) and the long duration of fertility from each insemination allowed for the continuation of intense selection for body weight in the male lines. Selection for body weight was less intensive in female than in male parental lines, so as to retain a reasonable production of settable eggs. Broodiness continues to be more of a problem in turkeys than in broiler breeders. Although there is little evidence of nonadditive genetic variation in egg production, commercial turkeys are produced by female line crosses, which while it may improve hatchability, mainly helps the breeders to control their genetic pool.

The use of artificial insemination in turkey reproduction has enhanced the feasibility of family structure of breeding flocks. Hence, family records have been always involved in turkey selection programs. Similar trends have only recently been observed in broiler breeding.

REFERENCES