FORMULATION OF BREEDING OBJECTIVES for POULTRY MEAT PRODUCTION

FRED T. SHULTZ, USA

SUMMARY

Economic values used in selection indexes are generally assumed to have a linear relationship to trait values. To the primary breeder in the commercial poultry industry, the relationships are non-linear (stairstep pattern) for most of the critical traits. The economic value of a trait (and the saleability of his stock) is determined by the performance of his stock relative to the competition. The point at which there is a substantial change in the economic value is referred to as a "breakpoint". If his stock is at the bottom of the breakpoint for a critical trait, he must quickly improve the trait or he will soon be out of business. If the trait is at the top of the breakpoint with a reasonable margin for error, selection pressure used to further improve the trait will be wasted.

As a consequence of breakpoints and the difficulty of translating commercial production values to pure line breeding values, the efficacy of including economic weightings in selection indexes is dubious. Restrictive selection indexes offer the best solution for the breeder. Methods developed for handling threshold traits should be considered.

INTRODUCTION

Selection index theory and application has been well developed and reviewed by many authors including Kempthorne and Nordskog (1959), Abplanalp and Eklund (1978), Lin (1978), Goddard (1983), Niebel and Van Vleck (1983), and Brascamp (1984). Economic values used in selection indexes are generally assumed to have a linear relationship to trait values. Methods have been devised for handling non-linear, but continuous relationships.

The realities of commercial breeding are vastly different from the textbook theory. This paper discusses the non-continuous, or "stairstep", relationships between economic values and trait values as they exist in the commercial poultry industry. Economic values are defined from the primary breeder point of view, namely, saleability of his product expressed as sales volume.

There are many factors affecting goal setting by the breeder and his customers. First, is the economic "tradeoffs" between traits. These generally take the form of "so many eggs are worth a certain increment of growth rate, etc. etc.". Hundreds of thousands of dollars have been expended by primary breeders over the last 20 years or more attempting to calculate these tradeoffs. However, costs of production and market prices are constantly changing. There are long term trends and short term fluctuations. Hence, any one determination may be misleading. Also the values of the traits themselves affect the relative value of traits (Shalev and Pasternak, 1983).
Tradeoff calculations should be directed more towards answering the "what if" type of questions rather than attempting to determine fixed economic values to use in indexes. For example, what if the price of feed increased 30%—would our competitive position be changed? Or, what are the feed price limits within which our competitive positions will not be changed?

Second, the primary breeder must be cognizant of who demands his product. Even in non-integrated situations the decision making party may not be the direct purchaser, the hatcheryman, but rather someone further down the line such as the processor. Under total integration, the influence of each level of production may vary from integrator to integrator. The choice of strains may be strongly influenced by the hatchery group of one customer and the processing group of another customer.

A selection index incorporating economic factors will be valid only for that segment of the industry it was intended. An index constructed for the primary breeder selling to the hatcheryman will be different from one constructed for selling to the integrator who controls the hatchery, grower, feed mill, and processing plant even though the same traits may be incorporated. An index useful for total industry evaluation (Harris et al, 1984) would be still different.

Third, the primary breeder must be aware of the probability of sudden shifts in market preferences regardless of who his direct customers are. The goals of the breeder must include such possibilities (Shultz, 1986). The selection index can anticipate such eventualities but only by compromising the effectiveness of its provisions for the known near term market.

Fourth, there are a variety of more subtle and obscure factors including tradition, consistency of performance, convenience, and conspicuousness. For example, a hatcheryman who is accustomed to increasingly higher reproductive performance is reluctant to break with tradition and accept lower reproductive performance. Sporadic egg number performance may constitute a serious risk. It is not convenient to control broodiness in parent flocks by management procedures—broodiness should be eliminated by genetics in parent female lines. Dead birds, which the poultryman must hand carry to disposal, are very conspicuous.

This paper is written in the context of the North American chicken and turkey industries. The considerations presented will apply, with minor modification, to the poultry industries of other continents.
THE PRODUCTION SYSTEM

The majority of the meat birds produced today are a 3-way cross resulting from a single line male parent crossed on a 2-way cross female parent. A smaller but significant portion of chicken broilers are a 4-way cross, the male parent being a 2-way cross. In many cases, the word "line" as used or inferred in the foregoing is more complex than the textbook connotation of "pure line" but this terminology will suffice for the purposes of this paper.

The use of specialized male line and female line parents serves two vital purposes in the production of commercial meat birds. First, there is a "division of labor". Since the male parent as well as the offspring do not need to lay eggs, the breeder can shift selection pressure from egg traits to meat traits in the so-called male lines. An additional advantage is obtained in that selection for meat traits will be less impeded by negative correlations with egg traits. The breeder can then afford to shift some, but not all, of the selection pressure from meat traits to egg traits in the female lines.

Second, heterosis can be used to better advantage. The 2-way cross of the female parent takes advantage of heterosis for rearing livability, egg number, fertility, hatchability, and laying house livability. The commercial meat bird has the benefit of heterosis for hatchability, livability, and potentially feed conversion and growth rate (perhaps more readily available in broilers than turkeys). Other production system efficiencies are obtainable.

The breeder constructing a selection index including economic weighting values is faced with the task of translating performance values of the commercial meat bird and the intermediate production line entities to the performance values of the pure lines in the actual breeding program. If linearity of the parameters involved is assumed, this task is not too formidable for the additive portion of the genetic variation. For the non-additive portion of the genetic variation, the task is not so easily accomplished.

ECONOMIC CURVE

The shape of the economic curve for many and perhaps all of the commercially important traits in the poultry meat industry is analogous to the usage curve for changing prices of alfalfa in least cost feed formulation. It was discovered by Rosenblatt, Shultz and Halloran (1958) that the usage curve for feed ingredients is related to ingredient prices in a stepwise rather than a linear fashion. Thus, as the price of alfalfa decreases the usage of alfalfa will increase, but not in a linear fashion (Halloran, 1959). It is a stairstep curve with long segments in which the price changes but the usage remains constant (Fig. 1). At each end of the constant segment, a very slight change in price changes the usage drastically (breakpoint).
In livestock breeding, we may substitute "Sales Volume" for Usage and "Trait" for Price. The breakpoints are usually steep inclines rather than vertical lines due to the large environmental variance making it difficult for the customer to precisely know the value of a trait in his production system.

In advanced breeding programs in established industries such as the broiler and turkey industries, the majority of the traits of importance to the primary breeder will be at a breakpoint in the curve. If his stock is at the bottom of the breakpoint for a critical trait, he must quickly rectify the situation or he will soon be out of business. If the trait is at the top of the breakpoint with a reasonable margin for error, selection pressure used to further improve the trait will be wasted.

There is considerable variation in the reproductive performance of parent breeder flocks. Hence it would appear that a low heritability trait such as egg number would be statistically hidden and thus translate to a linear economic scale at the breeder level. However with integration and larger production capacities, customers aided by computers are quite capable of sorting out strain differences. A breeder entering a new market area may get away with inferior egg number for a year or two but not much longer.

EGG WEIGHT

In the turkey industry, an egg is either classified as a hatching egg with a high value or as an eating egg with a relatively low value. A breeder cannot sell stock which produces only eating eggs. Unfortunately, sometime during the evolution of the turkey industry it was decided that hatching eggs should have a minimum weight. Today that minimum weight is 32 ounces to the dozen for one breeder's female line foundation (parent) eggs. The economic value of this trait to this breeder is illustrated in Fig. 2 (sales is expressed as "percent of potential" that the breeder might achieve within the limits of his production and marketing capabilities). This graph is of course an oversimplification because the eggs laid by one hen and by different hens vary considerably in size. Hence, the values as shown must be modified to allow for the natural variation.

At 32 ounces/dozen, the customers will consider the product good enough to buy. At 31 ounces/dozen, only one unit less, the egg is unsaleable. As egg size increases above 32, the value actually drops slightly because of the negative effect on egg number (otherwise, the customer doesn't care). The curve drops back to zero at the far right because many hens are recycled for a second season of lay. A turkey hen lays a significantly larger egg in the second season. Hence the first season egg size should not be too large because subsequent season eggs will be too big to set in modern day incubators.
The primary breeder with a small egg problem may circumvent this problem by selling poults instead of hatching eggs (which creates other problems). The customer has no way of knowing the size of the eggs from which his purchase came. However, if the customer's commercial flocks produce too high a proportion of smaller eggs, serious complaints will be forthcoming. The chicken broiler industry largely follows this latter course. The consequence is that acceptable egg size is less precise and the breakpoints of the curve will have more gradual slopes covering a greater range.

The above discussion assumes there is no relationship between egg size (chick and poult size) and market weight of the meat turkey.

FERTILITY

Virtually all broilers are produced from natural matings. Virtually all turkeys are produced by artificial insemination (AI).

Breeders must recognize that fertility is a compound trait consisting of "male fertility", "female fertility", and the possible interaction between the two. Male fertility is the resultant of libido and physical properties (milking response and musculature if AI), semen quantity, and semen quality. The components of female fertility are receptivity to male advances and physical properties (ease of eversion if AI), conditioning of sperm storage sites, number and size of sperm storage sites, management of the fertilization process, and no doubt many physiological factors. The female components are not as easily measured as the male components. Many have hormonal aspects. Many can be effectively selected artificially only with pedigreeing.

As with egg weight, fertility has a breakpoint between acceptable and unacceptable. However, this breakpoint is not as sharp as for egg weight due in part to large environmental effects (Fig. 3). Above the breakpoint, unlike egg weight, every increment increase in fertility is accompanied by an increase in economic value. This relationship is linear. Consequently, if the breeder's stock is above the breakpoint, this trait could be incorporated in the usual fashion into selection indexes. The biggest problem will then be the measurement of the trait in view of the discussion above. If the performance of the stock is below the breakpoint, the trait assumes primary importance and a selection index designed to make small increments of improvement will be inadequate.

Commercially, breeding stock is judged from two aspects, 1) the peak reached in the early part of the season and 2) how well fertility holds up (usually expressed as how badly it declines) in the latter part of the season. Customers will vary in their emphasis on these two aspects. Under natural mating in the broiler industry, mortality and poor condition of males late in the season is obvious not only in the hatchery records but visually in the hen house as well. Loss in libido is harder to discern.
With AI in the turkey industry, bringing in a set of younger males late in the season is sometimes used to alleviate poor late season fertility. Success has been only partial since the female is frequently the major cause of the loss. With the growing use of stud farms (males housed on one farm with continuous replacement, and semen carried to the breeder hen farms) the decline in fertility will become primarily a female problem. Males on stud farms will then be judged independently on the basis of longevity and semen volume and quality. If management of the stud farm has been proper, the hen will be accused of any low fertility on the hatch records. Consistency of performance from flock to flock is nearly as important as the mean.

At the grandparent stock level, the risk due to environmentally caused low fertility is assumed in large part by the primary breeder. In the broiler industry this comes about by the sale of chicks rather than eggs. However, variation in number of chicks hatched and therefore delivered to the customer is a mutual problem. In turkeys, the breeder may guarantee a minimum fertility of the eggs he sells thereby assuming the financial risk. The potential shortage of breeding stock from sporadic low fertility still remains as with broilers.

At the parent stock level, low fertility resulting in commercial chick and poult shortages is a risk borne entirely by the customer. Hence the breakpoint will tend to be sharper at the parent stock level than at the grandparent level.

HATCHABILITY

The economics of hatchability follow the pattern of fertility. There is a definite breakpoint relative to the competition. Above the breakpoint the relationship is linear. Below the breakpoint the breeder is in serious trouble and may have to concentrate on this trait alone.

The breeder recognizes two main classes of components of hatchability: 1) the embryo per se, and 2) the environment the embryo must develop in, namely the egg provided by the hen. External factors such as nutrition of the hen, egg handling procedures, and incubation conditions are assumed to be optimum, assumptions rarely achieved by some customers. To add to the complications, the translation of commercial hatchability to primary breeder pure line hatchability is difficult. Heterosis, frequently a factor in this trait, further compounds the situation. Again, the breeder is faced with the efficacy of measurements.

Many hatcherymen confound fertility and hatchability. The total number of viable chicks or poults hatched is their primary gage of the breeder's worth.
EGG NUMBER

Egg number is usually defined by primary breeders as the total number of eggs laid during a specified period. Cull eggs such as small, double yolk, misshapen, poor shell texture, etc. may be accounted as separate traits. In some cases the number of settable eggs may be used as the primary criteria.

Each of these traits are related more or less linearly with economic value. However, in the practical world, they all have breakpoints. The cull egg traits individually have little or no effect on primary breeder foundation sales unless their incidence rises to above the one to three percent level depending on the trait, the customer, and the season of the year. For example, it doesn't take very many double yolk eggs to get a customer excited. Collectively they have greater importance with a critical breakpoint between 3 and 5 percent of total eggs laid. Total eggs or settable eggs has an economic curve similar to the fertility curve (Fig. 3) and the same consequences apply.

THE GROWTH SYNDROME

Growth rate, feed conversion, edible meat yield, and fat content are so interrelated that one can no longer consider each separately. It is convenient to discuss them as components of the growth syndrome. Except for growth rate (usually defined as total body weight at some chosen age), they are difficult to measure on the live individual bird, each for somewhat different reasons. The economic value curve for each component has one or more breakpoints.

Growth rate of broilers has a very steep breakpoint. The highly integrated industry measures growth rate in hundredths of a pound. A breeder cannot afford to be more than a very few hundredths (say less than 5) behind in order to stay competitive. In turkeys, the breakpoint is much less critical with important compensating traits such as conformation and yield. The definition "weight for age" is being replaced by "time to market weight". Growing house turnover time is critical in broiler production and becoming more and more important in turkey operations as turkey meat increases in year around sales.

A complication for the breeder peculiar to the growth syndrome in general and growth rate in particular is the wide variation in desired market weight. The broiler industry has split into two main classes, fryer (whole body and cut up parts) and nuggets. The turkey has long had a wide range of whole body market classes and in recent years the further processing variable has been added. Thus far the poultry meat breeder has not had to resort to a "two product" line. Sex dimorphism has been a help, but not without some drawbacks, with the males and females covering different market requirements.
Looking at feed conversion as a separate entity, as the customer tends to do, the breakpoint picture parallels that for growth rate. However, the trait is much harder to measure reliably. It is composed of several distinct components and no single measurement by the breeder adequately accounts for them all (Shultz, 1986). Fat is a different story. It takes a tremendous amount of industry experience before one breeder’s stock is known to be different from another’s. Since processors rarely include strain in their pricing structure, a clearcut breakpoint has not existed in the past. Yield has likewise enjoyed relative obscurity. Further processing including cutup parts and nuggets is focusing attention on edible meat yield. Critical breakpoints will ensue.

VIABILITY

Viability of the meat bird appears to have a linear economic curve within the limits of today’s surviving breeders. None-the-less, mortality does not have to rise very much, even in isolated incidents, before complaints are registered with the primary breeder. Parent stock mortality also must remain within traditional levels. Hence the breeder must continue to include viability as one of the more important commercial traits.

Effective selection for viability is difficult to achieve. The incidence is low. It is an all-or-none trait requiring special interpretation (Robertson and Lerner, 1949). Translating customer stock performance (2-way and 3-way crosses) to the breeder’s stock performance (pure lines) is an obscure process.

DISCUSSION

The primary breeders perform the function of improving the performance of the stock used by the industry. To the primary breeder, the economic value of a trait is determined by the performance of his stock relative to the competition. In only rare instances will a serious deficiency in one trait be balanced by superiority in other traits. As a result, the relationship between economic values and performance values are non-linear for most of the commercial traits of importance to the breeder. The economic curve for a trait follows a "stairstep" pattern (Figs. 1-3). The point at which there is a substantial change in the economic value is referred to as a "breakpoint". The relative economic value of a trait to a breeder may be only remotely related to the economic value of the trait in the industry as a whole.

As an example, if Breeder A is 5% behind Breeder B in settable eggs, then the economic value of egg number is much higher for Breeder A, who may elect to place most of his selection emphasis on egg number until his stock becomes more competitive. Even if Breeder C and Breeder D are equal for all traits, Breeder C may elect to place a high value on egg number and a low value on growth rate, whereas Breeder D may elect to do the reverse. The relative values of traits are determined by how the breeder perceives the future industry.
Competitors are changing also. Genetic changes made today won't be identifiable in the final product for three to five years. Since the economic value of a trait to the breeder depends on performance relative to competitors performance, the breeder must allocate the available selection pressure today on the basis of predictions of the competitors performance several years hence.

As a consequence of breakpoints, the efficacy of including economic weightings in a selection index to be used in a commercial breeding program is dubious. It can be done as one means of placing different emphasis on various traits. Such an index would probably be useful only for the short term. The assumptions upon which the index is based should be kept in mind at all times.

Restrictive selection indexes, perhaps with arbitrary economic weightings (Kempthorne and Nordskog, 1959; Abplanalp et al, 1963; Eisen, 1977; Niebel and Van Vleck, 1983; Brascamp, 1984), offer the best solution for the breeder. Thus, Breeder A above might use an index designed to maximize gains in egg number while holding certain other traits constant. Breeder D might devise an index to maximize growth rate while holding egg number constant. Methods developed for handling threshold characters should be considered (Robertson and Lerner, 1949; Dempster and Lerner, 1950; Pirchner, 1983).

Decision making for the breeder thus becomes essentially a 5 step process:

1. Know the performance of ones stock relative to competitors from industry results and inhouse testing programs.
2. Know the relative importance of traits in the customers' minds.
3. Decide which traits to change and how rapidly in order to maintain or improve ones competitive position. Decide which traits to hold as is. Decide which traits can be excluded from selection.
4. Construct restrictive selection indexes to best meet the decisions made above.
5. Monitor industry and genetic change.


Fig. 1. Usage vs Price — Alfalfa
(Sales vs. Trait — Breeding Stock)

(After Halloran, 1959)
Fig. 2. Sales vs. Turkey Egg Weight
Fig. 3. Sales vs. Fertility

Sales (percent of potential)

Fertility (percent)