BREEDING PLANS FOR POULTRY WITH EMPHASIS ON SUSTAINABILITY

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INTRODUCTION

Sustainability (*Nachhaltigkeit*) was first mentioned in the German literature in the early 18th century in connection with forest management. The original idea focussed on long-term availability of wood for the mining industry. We in agriculture have known the basic concept of sustainability for crop farming and animal production long before this became a popular term. Within less than two centuries, the world population has grown from one to more than six billion people. There is plenty of food for those who can afford to buy it, and affluent urban consumers are becoming more critical about food quality. Producers of meat, milk or eggs are faced with questions *re.* animal welfare, environmental pollution, health aspects of food (safety and nutritional value) and cost of production. Animal rights and consumer groups are getting increasing attention and political support for their demands to establish higher ethical standards for animal production, which has become a part of the sustainability discussion.

The poultry industry as we know it today developed rapidly during the second half of the 20th century as a specialized, cost-efficient sector of animal agriculture. Poultry breeders, who must take changing consumer attitudes into account, will have to communicate to the general public how they accomodate ‚sustainability' in their work.

PRACTICAL ASPECTS OF SUSTAINABILITY

Before describing the historical development and current structure of the poultry industry, we will try to define what we mean by sustainability in the context of poultry breeding. Several authors have used the term and presented definitions they prefer. Instead of discussing ethical or philosophical aspects, we will list the main economic criteria we consider essential from a commercial breeder's standpoint :

- the food product (eggs, poultry meat) must be acceptable to consumers in terms of quality, price and ethical criteria, i.e. there must be a **demand**
- production of eggs and/or poultry meat must be a profitable business at all levels of the production chain (primary breeders and multipliers ; egg producers and broiler growers ; processing plants and trade), i.e. there must be a **supply**
- the objectives of **sustainable poultry production** are then : (1) to minimize resources needed (land, feed, water, energy etc.) for the production of poultry meat and eggs ; (2) to minimize emissions (dust and ammonia into the air, N and P into ground water) ; (3) to meet ethical demands for animal welfare (‚five freedoms') ; and (4) to maintain genetic diversity as a basis for future adaptation to changing demand (economic, cultural, environmental ; new diseases).

Primary breeders must concentrate on a long-term approach to achieve the above goals.

HISTORICAL DEVELOPMENTS

Before asking how commercial poultry breeding fits into the perspective of sustainable animal agriculture, we like to remind readers of the following developments during the past century, which have shaped the present structure of the poultry industry :

- increasing **world population** and **urbanization**, with decreasing number of people directly involved in agriculture and increasing complexity of the food industry
- specialization and increasing **size of production units** in animal agriculture, supported by technical innovations to replace labor by capital
- increasing demand for **specified product quality** in large volume to supply the food chain and to sustain in transnational competition
- with growing size of production units: more professional management, focus on reducing **production cost** per unit product and awareness of changing consumer demand
- advances in **disease control**: improved general hygiene with all-in, all-out management, eradication of vertically transmitted diseases, vaccination against common diseases
- advances in **nutrition**: research to determine requirements; feed formulation according to the needs of specific flocks ; improved feed hygiene
- advances in **genetics** : development of special lines for egg or meat production ; systematic crossbreeding with special male and female lines; advanced computer software to estimate genetic parameters and individual breeding values

Following a series of company sales and mergers in recent years, there is only a very small number of primary breeders left, with their headquarters and breeding centers in Europe and/or North America, which control the genetic quality of the majority of laying hens, broilers and turkeys kept for efficient production of poultry meat and eggs in all parts of the world.

IS THE CONCENTRATION OF PRIMARY BREEDING A DANGER ?

The degree of concentration at the primary breeder level may appear alarming : only three major groups of companies are actively involved in the maintenance and genetic improvement of lines representing more than 80% of the world's layer, broiler and turkey population. Would we be more secure in the sense of sustainability if we had, say, 6 or 12 companies ?

Looking back at the mergers which led to the existing concentration and the consequences for remaining genetic variation, it seems that very little useful genetic variation was lost in the process. In fact, the current major players have a broader spectrum of combinations to offer and are less vulnerable by changing demand than smaller companies with a limited range of products used to be. Let us take a closer look at the following examples from the egg industry, where three groups of primary breeders dominate the international layer market :

- Erich Wesjohann (D) with Lohmann Tierzucht (LTZ), Hy-Line and H&N
- Hubbard-ISA (F) with ISA, Shaver, Babcock and Hubbard
- Hendrix Poultry (NL) with Hisex, Bovans and Dekalb

Since Lohmann AG bought Hy-Line (in 1978), the breeding programs of Lohmann Tierzucht and Hy-Line have remained completely separate and self-sufficient; no commercial pureline has been discarded unless it could be replaced by a more productive line. LTZ and Hy-Line operate like competitors, and the geneticists of the two breeding companies compete in their efforts to breed the best possible combinations for the world market.

LTZ started to breed egg-type chickens more than 40 years ago, based on a license agreement with H&N and purelines which were subsequently developed as a replicate of the H&N RRS program. Lohmann AG bought H&N in 1987 and later transferred the breeding program to Germany. Today, the gene pool of LTZ and H&N lines is considerably larger than it used to be before some decades ago.

We have no information how other groups of primary egg-type breeders manage their enlarged gene pools, but they are under similar economic constraints to justify keeping purelines which presently may not contribute positively to the ‚bottom line' of the company. Geneticists, aware of the potential benefits of reserve lines, have to allocate available facilities between currently used commercial lines and lines which may some day contribute to new strain crosses.

The broiler industry has also seen dramatic changes in terms of concentration at the primary breeder level and market shares for the companies involved. Presently, the two most popular products in Europe are Ross and Cobb, both known for high breast meat yield. Until a few years ago, LTZ was also a primary breeder of Lohmann and Indian River broilers. This business was sold and absorbed into the new AVIAGEN company. World-wide, the three major players in broiler breeding are currently:

- AVIAGEN (with Ross, Arbor Acres and Indian River)
- TYSON (with Cobb-Vantress and Avian)
- Hubbard-ISA (with Hubbard and Shaver)

An interesting aspect of this development is that the two companies with the highest market share each have one product with extremely high breast meat yield (Ross, Cobb) and another product with better parent performance and a less extreme broiler for the whole-bird market (Arbor Acres, Avian). Breeders who tried to combine all desirable traits in a single product, with acceptable parent **and** broiler performance, had to learn that their index misjudged a maket where breed decisions are typically based on expected profit for the processing plant (Ross or Cobb type) **or** the hatchery (Arbor Acres or Avian type), and not for an integration with balanced interest in the performance of parents and commercial broilers.

POPULATION SIZE AND INBREEDING AS A SUSTAINABILITY ISSUE

Geneticists responsible for current breeding programs have to find a balance between short-term and long-term genetic progress. Maximum long-term improvement can be expected with a selection intensity close to 50%, but actual selection intensity may be less than 10% for the complex index and close to 20% for the primary selection trait. A breeder using the ‚optimal' selection intensity may never see the long-term benefit of less intense selection.

Inbreeding is of no direct concern for the multiple-strain cross commercial layers, broilers or turkeys, but inbreeding due to high selection intensity can limit future genetic improvement. This danger has increased since the application of animal model breeding value estimation, and it has become more critical to monitor the family structure. The traditional approach to limit the rate of inbreeding has been to maintain large populations. Depending on the number of lines in a commercial breeding program and the position of each line in the commercial cross, the family structure may vary between 250 and 1000 full-sib families (50-100 sires each mated to 5-10 females). Large lines can be subjected to intense selection with less concern about

inbreeding. To reduce the rate of inbreeding, the number of offspring selected per parent (especially full brothers) is limited. Ameli *et al.* (1991) reported a rate of inbreeding around 0.6 % per generation in two White Leghorn lines under long-term reciprocal recurrent selection. There is no indication that this rate of inbreeding has become critical for these lines, which have been closed for more than 50 years and had a much narrower base when the breeding program started.

More informative than rates of inbreeding may be genetic parameters for the major selection criteria like egg production in layers. The following table 1 compares estimates from two publications, representing two White Leghorn lines in the 1970s (Flock, 1977) and two brown-egg lines about 25 years later (Savas *et al*., 1999) :

Table 1. Heritability for rate of lay at different age

Rate of lay in	Heritability	
weeks of age	1977	1998
21 – 28	0.58	0.28
29 – 36	0.23	0.11
37 – 44	0.21	0.23
45 – 52	0.24	0.25
53 – 60	0.25	0.25
61 – 68	0.25	0.26

If pureline data are used for breeding value estimation, different inbreeding coefficients are taken into account. To minimize the variation in inbreeding coefficients, it is customary to avoid matings of full- or halfsibs. The following table 2 shows the distribution of inbreeding coefficients for two commercial brown-egg lines (Savas *et al*., 1999):

Table 2. Distribution of individual inbreeding coefficients in two commercial lines

Inbreeding	Line A		Line D	
coefficient	Number	%	Number	%
< 3.0	629	24.4	2081	36.5
3.0 – 4.4	700	27.2	1925	33.8
4.5 – 6.0	633	24.6	963	16.9
> 6.0	616	23.9	728	12.8

As a further measure of the homozygosity of a population, we may study the allele frequency for polymorphic microsatellites. The mean allele frequencies for four purelines are presented in table 3**.** In all four non-inbred commercial lines the degree of homozygosity is quite low, with max. 14 % fixed alleles, whereas the inbred experimental line has a much narrower base.

Table 3. Allele frequencies for microsatellites in 4 commercial purelines compared to an experimental line (Arthur, 2001)

Line	Number of markers	Proportion of fixed alleles	Number of alleles/marker
A	89	4	3.06
B	92	10	2.59
C	87	14	2.60
D	97	14	2.32
Exp.	103	80	1.20

The experimental line has been used at Hy-Line in the 1960s for inbreeding experiments. Since more than 25 years sib matings have been avoided in this line. Both the number of fixed alleles and the small number of alleles per marker highlight the difference from the commercial lines. Despite the large proportion of fixed alleles, the inbred line still exhibits sufficient genetic variance for genetic progress to be attained within this line.

SELECTION CRITERIA IN THE CONTEXT OF SUSTAINABILITY

Since the beginning of systematic selection for egg production in layers or meat production in broilers, turkeys and water fowl, the breeding goals have become more complex and the list of selection criteria longer. Typically, more than 10 criteria are evaluated to get a reliable measure of total performance. The most important traits are given below:

Egg-type chickens	Meat-type poultry
Number of eggs per hen housed	Juvenile growth rate
Feed consumption per kg egg	Carcass value, breast meat yield
Shell quality (strength, color)	Feed consumption per kg meat
Livability, disease resistance	Livability, constitution

Considering the economy of egg and poultry meat production, we can demonstrate dramatic savings in terms of feed, mainly due to increased egg output or lean meat gain, but also a reduction in feed for maintenance. To produce the current world consumption of 50 million t of egg mass and 60 million t of poultry meat would have required approximately the following amounts of feed:

Table 4. **Changes in total feed consumption due to improved feed conversion ratio**

	For 50 million t eggs		For 60 million t meat	
Year	FCR	Feed (million t)	FCR	Feed (million t)
2000	2.10	105	1.70	102
1975	2.80	140	2.30	138
1950	4.00	200	3.20	192

At current feed prices, the world-wide savings due to increased productivity of laying hens and meat-type poultry compared to 1950 is of the order of 30-35 billion € per annum. Another way

of looking at the reduced production cost for eggs and poultry meat is in terms of purchasing power: the ‚average consumer' can spend 5-6 € per year more for other goods due to improved feed conversion in poultry, and more people can afford better nutrition including animal protein. The increased purchasing power for poultry products is even more dramatic if expressed in terms of what an industrial worker can buy per hour income:

Table 5. **Purchasing power of industrial workers in Germany per hour work (Flock, 2002)**

Item	1960-1970 kg	1998-2000 kg	Increase %
Eggs (number x 60)	1.338	10.002	748
Broiler (whole, ready-to-cook)	0.991	7.816	789
Beef (stew)	0.731	3.153	431
Pork (cutlet)	0.573	2.734	478

There is no doubt that chickens and turkeys convert feed to edible protein more efficiently than other species of farm animals (with the exception of milk), which is a strong economic point for sustainability of poultry in competition with other farm animals. When it comes to **ethical aspects** of poultry production, we have to deal with the demands of consumer protection and animal rights groups. Consumers want to be assured that the animals producing meat, milk or eggs are kept under reasonably good conditions.

An important measure of good management is low mortality during the lifetime of a flock. During the past 50 years we have seen a significant reduction in mortality due to improved general hygiene, eradication of vertically transmitted diseases (Leukosis, Mycoplasms), vaccination and genetic selection. If mortality rates exceed 0.1 % per week in layers or 0.5 % per week in broilers or turkeys, we can usually identify specific causes, e.g. viral or bacterial infections, imbalanced nutrition or management factors. Despite low heritabilities for mortality and fitness traits, primary breeders are trying to solve the following problems :

- ***Cannibalism*** : If layers are kept in large groups without beak-trimming and/or controlled light intensity, or if they are on unbalanced feed, they may develop cannibalism, which makes the change from conventional cages to floor systems a risky business. A related problem is aggressive pecking in turkey toms as they approach sexual maturity.
- ***Marek's Disease (MD)***: Vaccination of day-old chicks, combined with effective hygiene, will usually protect pullets against field infections, but the virus tends to mutate to more virulent forms, which makes genetic resistance highly desirable. Before effective vaccines became available, selection for different objectives (production *vs.* resistance) within split populations appeared to be a promising alternative to index selection (Flock, 1974).
- ***Osteoporosis*** : Many laying hens develop different degrees of osteoporosis during the course of a normal production period, which may lead to bone breakage at depletetion. Selection for improved bone strength has been shown to be effective, but possibly negatively correlated with shell strength (Bishop *et al*., 2000).
- ***Cardio-vascular deficiencies*** : Fast growing broilers and turkeys may exhibit excessive mortality due to ‚sudden death syndrome' or ascites, depending on environmental

conditions (temperature, feed composition). Genetic selection against this susceptibility has been practiced for a number of years and needs continued attention.

- ***Leg problems*** : Fast growing (male) broilers and turkeys are more affected than slower growing birds. The incidence has been reduced with the aid of family selection and new diagnostic tools, and selection for lower incidence continues.
- ***Excessive appetite*** : In the course of intense selection for juvenile growth rate, broiler lines have developed an excessive appetite, which makes controlled feeding of breeders (parents and grandparents) necessary. Management practices like ‚skip-a-day' feeding are being criticized by animal welfare groups who demand selection against excessive appetite.

Trying to solve special problems like those mentioned above follows from the general breeding goal to produce, easy-to-manage' birds. In the past, there has been continued pressure from the poultry industry around the world to address these problems. Ethicists with concern for animal welfare should notice that selection for lower mortality and stress resistance is part of ongoing breeding programs. If the rate of progress is slow, this is mainly due to low heritabilities rather than strong negative correlations with productivity.

CAN NATIONAL BREEDING PROGRAMS ADD TO SUSTAINABILITY ?

Some countries have tried in the past to support their local poultry industry by closing the borders for imports. In theory, this could support bio-diversity and reduce the risk of spreading diseases. We can count more than a dozen countries (China, India, Russia, Indonesia, Australia, South Africa, Turkey, Iran, Iraq, Kasachstan, Finland, Norway, GDR) which had national breeding programs during recent decades. The most common arguments in favor of national breeding programs have been (1) independence from imports ; (2) adaptation to local conditions; and (3) biosecurity. Preservation of genetic diversity would be an additional argument in the context of sustainability.

When borders were opened to imports with international competition, most local breeding programs collapsed, because they could not compete in terms of product quality and/or chick cost. We can learn from more or less successful cases. Most of the current European poultry breeding companies started with purelines and know-how from established breeding companies in North America and continued their business under conditions of intensive competition. When imports were first allowed into Australia a few years ago, all imported breeds exhibited excessive MD mortality. Since imports were only allowed as hatching eggs for grand parents, and since MD is not egg-transmitted, this indicated that the local strains of chickens were more resistant to the MD field virus. After effective MD vaccines became available, the imported strains soon gained popularity in the market.

From these examples we can learn that efficient production requires a combination of breeding, controlling the environment as much as possible, and competition in the market. Protection of national breeding programs against international competition leads to higher product prices for the consumers, without assurance that useful genetic diversity will be preserved.

IMPLICATIONS FOR OTHER SPECIES

What can breeders of other species of farm animals learn from poultry ? The design of breeding plans for different species is based on the same quantitative genetics theory, and advanced computer software for breeding value estimation is available to anybody who knows

how to use it. However, each species has its own advantages and disadvantages when it comes to applying general theoretical principles.

Pig breeding largely follows in the footsteps of poultry breeding and exploits the superiority of crosses between specialized sire and dam lines. Within-line selection is intense, based on line-specific selection indices. Major differences exist in logistics, because it is impossible to ship large numbers of piglets across continents like day-old parent chicks. Similar efforts are made in biosecurity to control diseases.

Cattle breeding is following completely different patterns. Breeding value estimation is based on field data which have to be adjusted for a number of environmental factors. Many daughters records are used available to evaluate sires, but the information per daughter is limited to few traits and sometimes biased. Semen from proven bulls is used worldwide, and the potential benefits of crossbreeding are used only on a limited scale. If a poultry breeder were asked to design a breeding program for dairy cattle, he may start with the following ideas :

- search for breed crosses which produce superior hybrids in terms of life-time performance
- establish sufficiently large, closed nucleus populations which can be subjected to more accurate recording of a complete list of traits
- define the ‚environment' for which future generations are to be developed and test cross-line daughters of test bulls under these conditions
- concentrate on life-time performance and constitutional traits
- try to learn more each year about the populations involved, not only from the analysis of data and estimated genetic parameters, but also from dairy farmers who may observe more than can be expressed in a standard data recording scheme.

Adaptation to local environmental conditions is obviously more relevant for cattle and other large farm animals than for poultry, and dairy cattle associations may know better why they are not following the lead of poultry breeders.

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