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Poultry genetics and breeding in developing countries

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DISTRIBUTION, MANAGEMENT AND PRODUCTIVITY OF POULTRY GENOTYPES

In most developing countries, there are two parallel poultry industries: one using high-performing commercial layer or broiler genotypes; and the other based on lower-performing, dual-purpose indigenous breeds.

The proportions in these two categories vary widely among countries, but in lower-income countries, indigenous stock comprises as much as 90 percent of the poultry population (Pym, Guerne Bleich and Hoffmann, 2006).

The critical distinction between the two forms of production relates to management: commercial stock are generally reared in confinement and housed in flocks ranging from 100 to 200 birds (small) to more than 10 000 birds (large). The birds are usually given compounded feeds, and the larger facilities are normally located close to urban areas. Indigenous stock are typically kept by families in rural and sometimes peri-urban areas, in small semi-scavenging flocks of ten to 30 birds, which are fed with household scraps and small amounts of other feed. Women and children are usually responsible for managing family flocks (Sonaiya, Branckaert and Gueye, 1999).

Performance differences between the genotypes are often very large.

Commercial layers developed from imported parent stock have the capacity to lay more than 300 eggs per year, while indigenous hens often lay only 40 to 60 eggs per year (Sørensen, in FAO, 2010). As well as the large difference in genetic potential to produce eggs, a very significant cause of the five- to eightfold difference in annual egg production is the time – 17 weeks – that a broody indigenous hen spends hatching a clutch of eggs and rearing the chicks to about seven weeks of age. During this time, she does not lay, which shortens the remaining time available for further egg production and means that she can produce only about 3.5 clutches per year.

Quantity and quality of feed is another significant factor in the disparity in annual egg production between the two genotypes. Commercial genotypes are normally provided with carefully compounded feeds, which include nutrients in the correct proportions for maximizing egg production. They are usually also fed *ad libitum*. The energy and protein intake of indigenous birds in scavenging flocks is determined by the scavenging feed resource base, and is usually quite limited, particularly in the dry season.

To maximize egg production, the capacity for broodiness has been bred out of commercial-strain layer hens. They are therefore incapable of natural reproduction, and their value in a village environment is thus quite limited.

The growth rate of indigenous genotype chickens is also generally much slower than that of commercial broilers. While broilers under typical confinement rearing may reach 2.0 kg live weight at five weeks of age, indigenous-breed male birds often weigh no more than 1.0 kg at 20 weeks (Sørensen, in FAO, 2010). This is a reflection of true genotype differences, but also of rearing environment, in which feed quantity and quality is the major factor.

Despite their lower productivity, in the village environment, the indigenous genotype birds have a number of advantages:

- The hens become broody, so can reproduce without the need for artificial incubation and brooding.
- They are agile and can run fast, fly and roost in trees, so can escape predators.
- They have been shown to be more resistant to bacterial and protozoan diseases and to parasitic infestations than commercial broilers or layers are.
- Their meat and eggs are generally preferred to those from commercial birds, not only by rural communities but also often by urban dwellers.

COMMERCIAL SELECTION FOR MEAT AND EGG PRODUCTION

The dramatic gains in poultry meat and egg production from individual birds in commercial flocks over the past 50 years are largely due to genetic selection in the nucleus breeding flocks of large global poultry breeding companies and the rapid transfer of these gains to the commercial cross-bred progeny.

This has been facilitated by high reproductive rates, short generation intervals, reduced environmental variation, large population sizes to minimize the detrimental effects of inbreeding, and the use of several differentially selected sire and dam lines.

To date, much of the improvement in performance has been derived from the application of quantitative genetic selection, with limited use of molecular technologies.

The large majority of commercial broilers and layers in developing countries have been produced from imported grandparent or parent stock originating from large global breeding companies. There are also a few smaller breeding operations that supply stock to regional markets.

Broilers

The continued annual productivity gains of commercial broiler flocks are a reflection of the complex and coordinated approach adopted by breeders to maximize performance. Breeders have selected for such traits as growth rate, breast meat yield, food utilization efficiency, skeletal quality, heart and lung function, and livability. This has had considerable positive effects on bird welfare, as well as on the environmental impact of production.

Over the past 30 years or so, genetic selection for growth rate, feed efficiency, yield and livability is estimated to have reduced the feed required to produce 1 tonne of chicken meat from 20 to 8.5 tonnes, a 2.4-fold reduction (McKay, 2008). ***This has had profound positive impacts on the environment and on the availability and cost of poultry meat to the human population.***

Breeders continue to pay attention to growth, feed efficiency, meat yield, skeletal quality, general robustness and disease resistance.

Layers

In commercial flocks, egg number, size, shell and internal quality, and layer livability, persistency of production and feed efficiency continue to improve, owing to ongoing selection for these and correlated traits.

Current average annual egg production is well in excess of 300 eggs per hen, and continues to increase by more than one egg/hen/year, while the annual feed requirement for producing 300 eggs is declining by about 200 g/hen. With some 6 billion layer hens worldwide, this translates into savings of more than 1 million tonnes of feed per year.

At present, layer breeding programmes focus on robustness and disease resistance, as reflected in significant improvements in livability and welfare. Considerable attention is also given to uniform size and colour of eggs and to freedom from shell and internal defects.

Both broiler and egg breeding programmes are now concentrating on molecular marker-assisted selection (genomics). This approach provides a means of identifying and selecting for or against the genes affecting production traits, particularly those that are difficult to measure, and for the genes affecting disease resistance.

GENETIC APPROACHES TO IMPROVED PERFORMANCE IN SUB-OPTIMAL CONDITIONS

The non-genetic factors mitigating against good performance from poultry in developing countries typically include:

- high temperatures;
- sub-optimal nutrition;
- increased disease challenge;
- sub-optimal housing and management conditions.

All genotypes are affected by these factors. Alongside efforts to improve the physical environment, possible genetic approaches include:

- selection in commercial genotypes for improved tolerance to prevailing conditions;
- cross-breeding between commercial and indigenous genotypes;
- introgression of genes from commercial genotypes, via back-crossing or cockerel exchange programmes;
- selection for improved performance in indigenous genotypes.

Selection in commercial genotypes

The genetic stock from which the large majority of commercial broilers and layers in developing countries are derived was selected for production under relatively ideal management conditions in temperate climates. Little if any emphasis has been given to tolerance to high temperatures or to sub-optimal management and feeding conditions.

High ambient temperature is probably the main factor limiting the performance of commercial broilers and layers in medium to large-scale production units in tropical developing countries. Other factors can be addressed at moderate cost by establishing appropriate management strategies, but the cost of facilities and the availability of a secure and reliable electricity supply make shed cooling problematic.

A relatively simple approach to improving heat tolerance in commercial stock, without having to develop separate full selection lines, is to incorporate single genes affecting feather cover into the parent lines of stock to be used in high-temperature regions. Reduced feather cover facilitates loss of body heat. Genes shown to be effective in conferring heat tolerance include naked neck *(Na),* scaleless *(sc)* and frizzle *(F)* (Cahaner *et al*., 2008). Commercial lines that express some of these genes are now available in some countries.

Irrespective of selection for heat tolerance, commercial broiler and layer genotypes require good management and feeding to realize their genetic potential for meat or egg production. They are not capable of good performance under semi-scavenging village conditions.

Several approaches have been used in efforts to incorporate the genes associated with superior egg and meat production in commercial strains into stock intended for use in less optimal environments. Such environments range from semi-scavenging village production systems, where virtually the only inputs are household scraps, through small-scale to medium-scale commercial operations, where birds are confinement-reared and fed with compounded diets, but are exposed to high ambient temperatures.

Cross-breeding

In many regions, local indigenous and commercial genotypes have been crossed in attempts to provide birds that are tolerant to local conditions while also capable of reasonable performance. In nearly all cross-breeding programmes, the cross-bred bird exhibits considerably better egg production and/or growth rate than the indigenous breed parent, but problems can be encountered with:

- loss of broodiness in hens, making them incapable of reproducing naturally;
- the need for maintaining separate parent lines/breeds and for the annual replacement of F1 cross-bred chicks;
- the need for additional inputs (particularly feed) to achieve the birds' genetic potential for production;
- a change in appearance and "type", which affects the birds' acceptability to farmers and the consumers of poultry eggs and meat;
- erosion of the genetic resource.

Introgression and cockerel exchange

Another strategy for improving the performance of local populations is through introgression of genetic material. This can be achieved though back-crossing or cockerel exchange programmes.

Experience has shown that for a back-crossing programme to be sustainable, increasing levels of supplementary feed and improved management and disease control are required as the frequency of exotic genes increases. Cockerel exchange programmes involve distributing cocks of improved breeds to smallholders. However, several reports have concluded that this type of improvement has not changed the basic populations, except for contributing to a larger variation in plumage colour (Besbes, 2008).

Selection within indigenous breeds

Selection for improved production within indigenous breeds or ecotypes is problematic for the following reasons:

- Effective selection depends on accurate recording of pedigree and performance.
- All birds should be subject to similar environmental variation.
- Egg production under cage confinement may be poorly correlated with reproductive performance under semi-scavenging conditions.
- The components of reproduction under semi-scavenging conditions are very complex, making selection under these conditions exceedingly difficult.

Despite considerable genetic variation in most indigenous breeds for egg and meat production, the complexity of the production system and of the desirable traits presents considerable obstacles to effective selection for improved performance. There are examples where performance has been improved through this approach, but they are few and the gains have been modest (Sørensen, in FAO, 2010).

GENETIC DIVERSITY AND CONSERVATION OF GENETIC RESOURCES

There is widespread concern in developing countries that as a result of replacement of low-producing breeds, urbanization, crossbreeding and the stamping out of flocks in response to outbreaks of disease, the world is losing valuable and irreplaceable poultry genetic material.

Concerns about a loss in genetic variability in commercial poultry strains have also been voiced following dramatic global reductions in the number of commercial poultry breeders and the number of populations under selection over the last 20 years (Arthur and Albers, 2003). ***A major concern is that the reduced genetic variability could place the industry in jeopardy in the event of a major disease outbreak involving new virus strains.***

The State of the World's Animal Genetic Resources, *published by FAO, found that of 2 000 avian breeds for which data were available, 30 percent were reported at risk, 35 percent not at risk, and the remainder were of unknown risk status* (Hoffmann, 2008).

In the past, genetic diversity was largely determined by phenotype. Recently, DNA analysis has provided an invaluable new technology for determining the relationships among individuals, breeds and ecotypes. Clustering methods using microsatellite markers have been effectively applied to assign individuals to their breed of origin, and to determine the degree of genetic diversity between populations.

Recent studies have shown a large range of within-breed or ecotype heterozygosities, of 28 percent for a fancy breed, 40 percent for white-egg layers, 45 to 50 percent for brown-egg layers, 50 to 63 percent for broilers, and 67 percent for a population of village chickens (Tixier-Boichard, Bordas and Rognon, 2008).

Studies in Africa have suggested that village chickens do not seem to exhibit a typical breed structure. While there is a high degree of between-bird variation in a village, differentiation between populations is observed only among those separated by large geographical distances. There is therefore considerable exchange of birds among adjacent villages. This suggests that many countries' claims to have a significant number of breeds or ecotypes of indigenous village-type chickens in a region may well be found by molecular measures to be based on a minimal degree of genetic diversity.

An integrated approach to breed characterization is required, and data on production systems, phenotypes and molecular markers should be combined to facilitate this. A comprehensive description of production environments is needed, to improve understanding of the comparative adaptive fitness of specific animal genetic resources.

The characterization of defence mechanisms against pathogens should be a priority, given the significance of the threats posed by epizootics and climate change. Field and on-station phenotypic characterization is therefore highly desirable.

REFERENCES

Arthur, J.A. & Albers, G.A.A. 2003. Industrial perspective on problems and issues associated with poultry breeding. In W.M. Muir and S.E. Aggrey, eds. *Poultry genetics, breeding and biotechnology.* Wallingford, UK, CABI Publishing.

Besbes, B. 2008. Genotype evaluation and breeding of poultry for performance under sub-optimal village conditions. *Proceedings of the 23rd World's Poultry Congress*, Brisbane, Australia, July 2008. CD-ROM.

Cahaner, A., Druyan, S., Hadad, Y., Yadgari, L., Astrachan, N., Kalinowski, A. & Romo, G. 2008. Breeding broilers for tolerance to stresses. *Proceedings of the 23rd World's Poultry Congress*, Brisbane, Australia, July 2008. CD-ROM.

FAO. 2010. *Chicken genetic resources used in smallholder production systems and opportunities for their development,* by P. Sørensen. FAO Smallholder Poultry Production Paper No. 5. Rome.

Hoffmann, I. 2008. The global plan of action for animal genetic resources and the conservation of poultry genetic resources. *Proceedings of the 23rd World's Poultry Congress,* Brisbane, Australia, July 2008. CD-ROM.

McKay, J.C. 2008. The genetics of modern commercial poultry. *Proceedings of the 23rd World's Poultry Congress,* Brisbane, Australia, July 2008. CD-ROM.

Pym, R.A.E., Guerne Bleich, E. & Hoffmann, I. 2006. The relative contribution of indigenous chicken breeds to poultry meat and egg production and consumption in the developing countries of Africa and Asia. *Proceedings of the XII European Poultry Conference*, 10–14 September 2006, Verona, Italy. CD-ROM.

Sonaiya, E.B., Branckaert, R.D.S. & Gueye, E.F. 1999. Research and development options for family poultry. *First INFPD/FAO Electronic Conference on Family Poultry.* December 7 1998 to March 5 1999. Introductory paper.

Tixier-Boichard, M., Bordas, A. & Rognon, X. 2008. Characterization and monitoring of poultry genetic resources. *Proceedings of the 23rd World's Poultry Congress,* Brisbane, Australia, July 2008. CD-ROM.