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REVIEWS

Research and investment in poultry genetic resources – challenges and options for sustainable use

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The global poultry sector is divided into a large-scale commercial sub-sector dominated by international, vertically integrated companies, and a small-scale sub-sector that provides up to 90 percent of total poultry production in some of the least developed countries. The fast reproduction cycle, low unit costs, economies of scale in research and appropriation, and control of the produce are driving factors in the commercial sector. Private research concentrates on technologies that are likely to result in market applications and returns to investment. Private incentives for animal research are strongest where markets for improved technology are large, technical advances can be made quickly, and intellectual property can be protected. To date, technological protection strategies and contractual practices, rather than formal intellectual property rights strategies, have dominated in the commercial poultry sector. Poultry breeding companies have developed a highly successful way of protecting their intellectual property investment in superior breeds by exploiting heterosis, and the deleterious segregation of hybrid stocks in the next generation. Thus, by restricting access to the pure parent line stock (a form of trade secret) and by selling F1 generation birds, a breeding company remains the sole supplier of useful material. Patents do not yet play a role in poultry breeding, but breeding for disease resistance might change this in the future.

This paper explores the flow of poultry genetic material between developed and developing countries, investments in the poultry sector in developing countries, and economic and legal issues involved. In terms of genetic resources, the main questions concern how the division in the poultry sector affects the full portfolio of poultry genetic resources and if this division has an impact on the traditional small-scale sub-sector. The analysis is based on country reports to the First Report on the State of the

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World's Animal Genetic Resources process, studies on flow of genetic material and commercial transactions, and genetic distancing.

Keywords: genetic variability; breeds; genetic erosion; research

The sector

Poultry is kept in a wide range of agro-ecological zones and production systems, and under different economic regimes. Production targets also differ and include both subsistence farming with a high proportion of home consumption and commercial farming with no home consumption. The global poultry sector is divided into two distinct sub-sectors: the commercial sub-sector dominated by international, developed-country based and vertically integrated companies, and the small-scale sub-sector that provides up to 90 percent of total poultry production in some of the least developed countries.

Subsistence farmers do sell birds, but only in cases of cash needs, and keep birds mainly for home consumption or for social, religious or cultural reasons. Sonaiya *et al.* (1999) identified three production systems for family poultry - free range, backyard and small-scale intensive with a productivity of 20 - 60, 30 - 100 and 80 - 150 eggs/hen/year, respectively. In addition to food (meat, eggs), such poultry provide several products and services including feathers and manure. It also serves as dowry, is used in funerals and sacrifices, and generates income through cock fighting. For most religious and socio-cultural purposes, the required sex and colour of birds are prescribed (Sonaiya *et al.*, 1999).

As incomes rise, people generally prefer to spend a larger share of their food budget on animal protein, and as a result, meat and dairy consumption tends to grow faster than that of food crops. The past three decades have seen extensive growth in the consumption of livestock products, especially in newly industrializing countries - the so-called "Livestock Revolution" (Delgado *et al.*, 1999). Annual meat consumption per person in developing countries more than doubled between 1964-1966 and 1997-1999, from 10.2 kg per year to 25.5 kg — a rise of 2.8 percent per year. The rise was particularly rapid for poultry, where meat consumption per person grew more than fivefold. World egg production is forecast to increase by 30% by 2015 as compared to 2000, with higher growth rates in developing countries (FAO, 2003). A strong consumer preference for poultry meat over other meat types has been observed. Most of this demand will be met by intensive production systems located predominantly in peri-urban areas. In addition to the environmental problems related to intensive poultry production, this development may pose a threat to the livelihoods of small farmers (Upton, 2000).

Changes in market demands are due to technological advances, which lower the relative prices of animal products, product innovations (*e.g.* value-added foods), and change in consumer preferences. The poultry industry had more rapid technological change in production practices than the one of other animal species, which led to reduced retail prices for poultry meat as compared to other proteins. The poultry industry also took advantage of increased consumer preference for leaner meats and for processed poultry food products in developed countries.

Another major fact supporting intensive production systems is the globalization of the market for improved livestock genetics. Improved access to international markets and the growth of world trade has enabled livestock breeding companies to sell their products worldwide. The increase in the size of the potential market strengthens incentives to invest in research to develop new animal production inputs and breeding stock (Narrod and Fuglie, 2000).

This paper explores how the division of the poultry sector into a traditional/small-scale and a commercial segment affects the full portfolio of poultry genetic resources, and the production environment. It also touches on investment in developing countries poultry sector, and the economic and legal issues involved, including the flow of poultry genetic material between developed and developing countries.

Poultry genetic resources and breeding

Animal genetics resources (AnGR) are commonly grouped by their origin as locally adapted breeds or exotic, and by their breeding history as locally developed or commercially bred[2]. Selection objectives and criteria are not always clearly defined for locally developed breeds, while commercial breeds usually have their origins in breeding programmes which are based on animal identification and performance recording of individual animals.

Local breeds in developing countries often have no defined phenotypic patterns, but are distinguished by one or more single features, *e.g.* having a naked neck or being fully feathered (Tadelle *et al.*, 2003). Although there are only a few breeds that have been formally described, this number is increasing (DAD-IS). These local birds are mainly used in the subsistence and small-scale sector of developing countries, supplying most of the eggs and meat consumed. The system of management influences the choice of breeds, with the free range system using almost exclusively local breeds. There are reports of local birds having the ability to use high fibre feeds (Diambra, 1990; El Houadfi, 1990) and fast growth rate (Olori and Sonaiya, 1991). Indigenous chickens appear to have an inherent scavenging and nesting habit, are more resistant to various diseases, less prone to predator attacks and can survive under harsh nutritional and environmental conditions (Oluyemi *et al.*, 1979; Kitalyi, 1998; Minga *et al.*, 2004). Hence, selection in local breeds appears to be targeted more at adaptation to harsh environments and resistance to disease rather than enhanced production.

Since the introduction of modern poultry breeding in the 19th century, a multitude of breeds has emerged. The classic "pure" breeds were developed using distinct local populations that differed in many phenotypic traits such as plumage colour, feathering pattern, and comb type. Modern specialised breeds and lines have been developed since the 1950s in developed countries to produce high output in one or few major traits. Breeding goals were directed to achieve high performance in meat and/or egg production traits. To date, most of the livestock in developed countries (and increasingly so in developing countries) is kept in more or less controlled conditions that reduce or eliminate the dependence on the surrounding environment. Even feed ingredients are not necessarily produced locally as they are increasingly available on international feed markets. Detachment from environmental influence is most pronounced in landless livestock production systems, such as for poultry and pigs kept in intensive conditions. A

[2]**Locally adapted breeds** have been in the country for a sufficient time to be genetically adapted to one or more of traditional production systems or environments in the country; **Indigenous breeds**, also termed autochthonous or native breeds and originating from, adapted to and utilized in a particular geographical region, form a subset of the Locally Adapted Breeds.
Exotic breeds are maintained in a different area from the one they were developed and including breeds that are not locally adapted. Exotic breeds comprise both **recently introduced breeds** which were imported over a relatively short period of time within the last 5 or so generations and **continually imported breeds** whose local gene pool is regularly replenished from one or more sources outside your country. Many of the breeds used in intensive production systems or marketed by international breeding companies would be in this category (FAO, 2001).

consequence of the uniformity of environmental conditions is the need for fewer breeds, contributing to the reduction of livestock diversity (Tisdell, 2003). Current breeding goals also include improved animal health and metabolic stability (*e.g.* bone structure, integrity of vital organs), animal behaviour and product quality. These processes are driven by environmental problems created by intensive poultry husbandry, increased consumer awareness, and animal welfare movements in developed countries. In the United States there is an increased consumer interest in range and pasture-reared chickens, eggs and turkeys. In some situations production for these niche markets appears to be falling short of demand (USA Country Report). Associated or external factors (*e.g.* waste management) or pressure from special interest groups (*e.g.* animal rights) may drive breeding costs up by requiring adaptation to unforeseen scenarios, perhaps by inclusion of fitness traits into selection programmes. Human *vs.* animal cereal consumption issues need to be addressed and the nitrogen and phosphorus pollution from intensive poultry farming reduced. Hence, constant improvements in feed conversion ratio (FCR) in poultry are a necessity and an obligation for breeding companies, for environmental and economic reasons. Hence, FCR for meat and egg production in commercial poultry has been reduced by half in the past 50 years and is now at about 2:1 for broilers and 1.7 kg/dozen for layers. Fancy breeds have far higher FCR than commercial lines (Flock and Preisinger, 2002; Pingel, 2003).

Economic drivers and property rights

Private incentives for animal research are strongest where markets for improved technology are large, advances in husbandry can be implemented relatively easily and quickly, and where intellectual property can be protected (Narrod and Fuglie, 2000). Private research tends to concentrate on technologies that are likely to result in market applications in the near future. In the commercial poultry sector the driving factors are the fast reproduction cycle and low unit cost, economies of scale in research and the appropriation and control of produce. The unfavourable association of traits for egg and meat production led to an early split between breeds for either egg or meat production (Pingel, 2003) and to further specialization of lines selected to become providers of parent males or parent females in industrial crossbreeding schemes.

Local breeds are kept and exchanged by a multitude of small farmers while commercial breeding tends towards consolidation, independent of the legal form of the enterprises (cooperatives or companies). Consolidation in the animal industry depends on reproductive rate, portability and transportation costs of breeding stock, and the costs associated to breeding. Consolidation is highest in the poultry breeding industry because the reproductive rate is highest, and eggs and day-old hatchlings are highly portable. In the 1950s, there were numerous primary breeders in Western countries. In the early 1980s there were 20 breeding companies all over the world. Today, three groups of primary breeders dominate the international laying hen market. There are four major companies in broiler breeding worldwide (Flock and Preisinger, 2002). The consolidation process is expected to have ended, and the current players are able to provide the global supply of 700 billion eggs needed for final products (Preisinger, 2004). The consolidation of the poultry breeding companies and the high degree of vertical integration in the broiler and layer industries enable private breeders to capture a greater share of the economic gains from research investments. There are some smaller breeders in Israel, India, and others in China, Taiwan and Vietnam producing yellow feathered bird breeds and some red and some black birds. In some regions, these birds hold 50 to 90 percent of the market, all being supplied by local breeding companies (Pingel, 2003). Local poultry achieves high prices, particularly in certain Asian countries (Dolberg, 2004).

Increased industrialization has led to heightened interest in protection of intellectual property. The boundaries of the intellectual property system widen as industries extend their orbit of operation by developing and applying innovative technologies. This expansive process is pragmatic and is likely to succeed, except in cases where other interest groups voice their fierce and relentless opposition (Cornish, 1999). To date, technological resources and contractual practices, rather than formal intellectual property rights strategies, have been the norm in the poultry industry. Poultry breeders have developed a successful way of protecting intellectual property investment of their breeds. Availability of breeding stock is usually restricted to grandparent birds or to a single sex of a parental breed, in the case of a terminal sire, ensuring that breeding companies remain the sole suppliers of economically useful material. Attempts to regenerate from these hybrids do not yield birds with competitive field performance due to loss of heterosis. Patents do not yet play a role in poultry breeding, although breeding for disease resistance might change this in the future.

The few existing patents in poultry breeding cover identification methods for single genes. In countries excluding patentability for animal species as such[3], it is not feasible to patent existing breeds or lines of poultry. From the breeding companies' point of view, disclosure of the characteristics of the lines, a necessary step for the patenting process, would imply a set genetic standard for the population, which is inconsistent with their goals to continuously improve their products. There are also trade secrets embedded in the combination of the individual lines and the knowledge of hygiene and husbandry practices, and feed formulation. Unless the clients are under contractual obligation not to do so, it is possible to continue breeding using the products provided by the breeding companies but the resulting progenies will not be economically competitive in the markets these companies hold. There are many patents in the poultry industry as a sector. For instance, patents are abundant in poultry processing equipment. These patents generate income from royalties and do not deny access to users, but may establish thresholds for new manufacturers.

Breeds versus genetic variability

Breeds are the basis of animal genetic diversity. Breeds are defined by FAO as cultural rather than technical units[4]. Genetic diversity may be described in terms of genetic distances through some molecular genetic methods, such as microsatellite markers. The more distant breeds are on a phylogenetic tree, the more genetically different they are. High genetic variability can be found within breeds with large populations and flock sizes

[3]Pursuant to art. 27.3 (b) of the TRIPs Agreement, stating that Members may exclude 'plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes'.

[4]**Breed**: either a subspecific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity. Note: Breeds have been developed according to geographic and cultural differences, and to meet human food and agricultural requirements. In this sense, breed is not a technical term. The differences, both visual and otherwise, between breeds account for much of the diversity associated with each domestic animal species. Breed is often accepted as a cultural rather than a technical term (Guidelines for the Development of Country Reports, FAO).

and limited inbreeding. FAO has initiated the Measurement of Domestic Animal Diversity (MoDAD) which provides recommendations about sampling of individuals for genetic diversity studies. Lists of recommended microsatellite loci for genetic distance studies in cattle, chicken, pig and sheep can be found in FAO's Secondary Guidelines (FAO, 2004). Furthermore, at the request of FAO, a panel of experts, the FAO/ISAG advisory group has decided on a set of microsatellite loci for each species to be used as the standard marker set to calculate genetic distances and to quantify genetic diversity. The adherence to such recommendations is the basis for a reasonable comparison of parallel or overlapping studies of genetic diversity and a necessary prerequisite to combine results in meta-analyses and in the construction of phylogenetic trees. A questionnaire study was conducted to evaluate the actual application of FAO recommendations in past and ongoing diversity studies (Baumung *et al.*, 2004). Results show that the recommended loci are widely used in cattle and pig, but not in studies with chickens. Only one out of eight projects with chickens reported that the FAO recommended list was used entirely. Fifty-five different microsatellite loci were used in five projects in addition to the 25 recommended ones. The FAO/ISAG advisory group revised the current recommendations and lists of microsatellite markers in 2004 (Hoffmann *et al.*, 2004).

Genetic diversity measured at the molecular level does not always correspond to phenotypic breed diversity, because a long history of exchange, upgrading and crossbreeding has sometimes created new genotypes within old phenotypes. For example, breeders of fancy breeds are mainly concerned about the phenotype, whereas the genotype of phenotypically different breeds may be very similar. The re-creation of extinct breeds may occur by employing crosses aimed at reproducing a phenotypic standard. These re-creations may be very sensible in socio-culturally motivated conservation of old breeds adapted to a specific landscape - considered agricultural and landscape heritage - but should not be confused with maintenance of genetic variability. Two lines of arguments should be distinguished: the breed as a social construct with certain phenotypic characteristics and defined by governments as custodians of biodiversity under the Convention on Biological Diversity CBD[5], and the genetic variability at the genomic or locus level. The discussion on AnGR diversity, its characterisation and its management, is not an easy one. The same is true for poultry genetic resources (PoGR). The effective population size of these breeds can decrease in a relatively short period of time, if, as in the case of fancy breeds, intense selection for exhibition traits takes place. Inbreeding, genetic drift and bottlenecks can exacerbate the situation, placing breeds at risk[6].

Genetic diversity and the erosion of genetic resources

Despite its importance for food security, PoGR have not yet received the necessary public attention. The data entry on poultry breeds is scarce in the FAO based Domestic Animal

[5]Art. 2 of the Convention on Biological Diversity defines genetic resources as 'genetic material of actual or potential value', and genetic material as 'any material of plant, animal, microbial or other origin containing functional units of heredity'.

[6]**Breed at risk**: any breed that may become extinct if the factors causing its decline in numbers are not eliminated or mitigated. Breeds may be in danger of becoming extinct for a variety of reasons. Risk of extinction may result from, *inter alia*, low population size; direct and indirect impacts of policy at the farm, country or international levels; lack of proper breed organization; lack of adaptation to market demands or perceived as of lower performance. Breeds are categorized as to their risk status on the basis of, *inter alia*, the actual numbers of male and/or female breeding individuals and the percentage of pure-bred females.

Diversity Information System DAD-IS but improving over the years (Scherf, 2000; Weigend and Romanov, 2002). Countries have entered data on 14 avian species and 1049 breeds into the DAD-IS database, which represent only 16% of all breed entries. From the data on poultry genetic resources provided by countries to DAD-IS it is obvious that breeds recorded in Europe and North America are mostly threatened by extinction, whereas data is insufficiently reported for other regions. About 50% of the poultry breeds registered in DAD-IS are classified as being at risk – this is the highest percentage of breeds at risk of all species contained in DAD-IS (*Figure 1*). Commercial poultry breeds are not catalogued in DAD-IS, nor the lines kept in reserve by the breeding companies or at universities. Commercial poultry, however, supplies a high percentage of poultry meat and eggs in developing and developed countries.

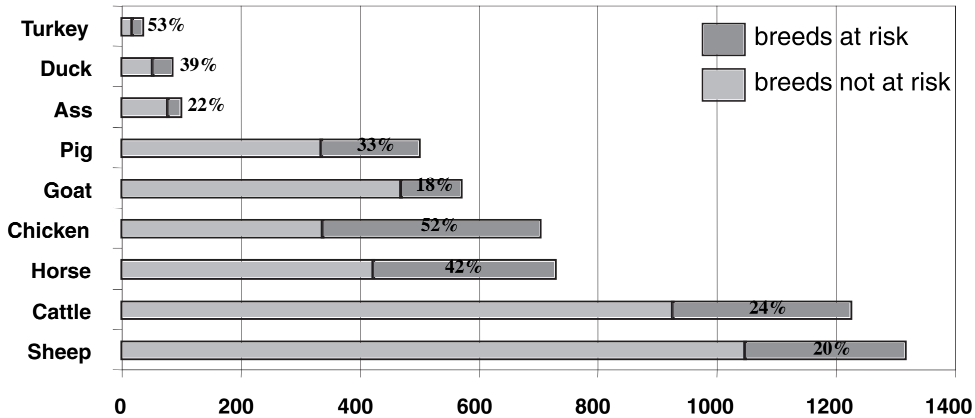

Figure 1 Breeds of farm animals at risk around the world (FAO).

Commercial poultry breeders sell various products, most of which are the result of mating three or four lines. These lines must be continuously developed at the pedigree level and reserve lines also kept despite the constant economic pressure to dispose of surplus lines (Flock and Preisinger, 2002). From the genetic variability point of view, commercial breeds cover a broad range of poultry genetic diversity which can also be found in fancy breeds. Loss of genetic diversity does not yet seem to be a major issue, since fixation of alleles and degree of homozygocity are low (Flock and Preisinger, 2002; Hillel *et al.*, 2003). In recent years, however, breeders of commercial white-egg layers have been concerned about reduced genetic variability and future response to selection. This is due to the genetic origin of white-egg layers, which go back to one breed, the Single Comb White Leghorn. The genetic basis for brown egg layers or broilers is somewhat broader, mainly coming from four breeds. Despite the fact that the gene pools of the primary breeders are not unique but overlap due to the narrow genetic base of the original breeds, the massive merging of breeding companies in recent years, and the disposal of reserve lines for economic reasons should call for attention to the need for conservation of genetic variation among breeds and lines (Hillel *et al.*, 2003). Hence, while sufficient genetic variation seems to be maintained within the commercial breeds, lines also disappear, and access to those lines is restricted.

Flow of genetic material and conservation

Flow of poultry genetic material from developing to developed countries played a role in the past, mainly in qualitative terms. All modern commercial chicken breeds trace back to breeds that were already developed in northern hemisphere countries one hundred years ago. Many of these breeds were built up from a small number of imported chickens. These original imports probably date back hundreds of years, and Asian countries are the most important source. This is not surprising because the South Asian Red Jungle Fowl is the most probable single ancestor of all poultry breeds (Hillel *et al.*, 2003). Commercial broiler paternal grandparent breeds are mainly derived from the White Cornish breed, which was developed in England from Asiatic fighting stocks (Hillel *et al.*, 2003), while maternal broiler grandparents breeds are heavily based on White Plymouth Rock breed.

Breeds and lines from developing countries are of interest to ongoing research in gene mapping. The Egyptian Fayoumi showed more resistance to viral diseases than other breeds of chicken (Pinnard *et al.*, 1992) and raised interest of the U.S. Poultry Gene Mapping Project (The Iowa Stater, 1997). Another example is the introgression into poultry breeds of the naked neck gene, which seems to improve the resistance to heat. Heat stress in birds is a concern in lower input poultry operations, since it causes high mortality and reduces productivity, especially during the hot season. This is important because although commercial poultry is mainly bred in northern hemisphere countries, it is exported globally. Birds with this genetic makeup have skins that lack or have greatly reduced feather tract numbers. Naked-neck breeds, probably of Malaysian origin, have thrived worldwide for more than 200 years. Today, naked or featherless chicken are crossed on commercial broilers in Israel (Yaron *et al.*, 2004). An increase in egg production was reported through incorporating naked neck genes in a crossbreeding programme of local Fayoumi (Mathur *et al.*, 1989), and on egg production, egg weight and feed efficiency of chicken under heat stress (Horst and Mathur, 1992).

Developing countries are concerned that products from genes from their native breeds will be patented and that access to them will be limited without the countries of origin receiving fair and equitable benefit. At the policy level, the relationship between the provisions of the WTO-TRIPs Agreement and the CBD raises concerns in those countries. Mainly underscored is that the CBD recognizes the right for countries providing access to genetic resources to obtain appropriate benefit-sharing measures. On the other hand, such rights may be undermined when the appropriation of genetic resources occurs under intellectual property regimes. In addition, while the CBD states that access is subject to prior informed consent (PIC), the TRIPs Agreement does not contain PIC requirements. Commercial breeding companies present biosecurity as the argument against introducing foreign animals into commercial flocks. This, however, may change if progress in gene technology advances. To date, methods in molecular genetics have little importance for commercial poultry breeding, but marker assisted selection for traits that are difficult to measure (*e.g.*, disease resistance) or that occur later in life (*e.g.*, persistency of lay) may become feasible in the future (Pingel, 2003), especially after relevant statistical methods are refined.

In quantitative terms, most genetic material flows from developed to developing countries. In developing countries, the impact of importing exotic breeds is multifaceted and touches socio-economic as well as genetic diversity aspects. Importing exotic breeds into a production environment suitable to them will be economically advantageous for the individual importer – as is the case of commercial poultry lines in industrial production systems. On the other hand, there are many examples where upgrading of poultry stocks and crossbreeding programmes in developing countries (*e.g.* “Operation coque” in West Africa) have largely failed because the animals did not perform in the harsh and disease-prone environments, leading to economic losses for the small producers (in Nigeria: Adegbola, 1988; in Malawi: Safalaou, 1997; in Niger: Kaiser, 1990 and in Tanzania: Katule, 1989; Katule and Mgheni, 1990). Hence, there is little loss of local PoGR through such direct intervention. Besides upgrading programmes with exotic breeds there are probably also some hybrid animals from commercial farms used in breeding. As there has been at least one attempt at crossbreeding in most countries, many existing birds are crosses, to various degrees, of the original local birds with the exotic breeds used for these programmes (Rhode Island Red, Leghorn, Australop and Wyandotte; Sonaiya *et al.*, 1999).

Local PoGR are probably more threatened through the indirect impact of market competition if the intensive commercial sub-sector gains a certain market share in the country. This can even happen if markets for local and commercial poultry are segmented – for example if spent hens are sold in rural areas competing with local chicken because of their similar tough meat, or surplus broilers from contract farming, or even poultry meat parts. In such cases, the livelihoods of farmers that supply the same markets with less productive breeds may be threatened, and if they remain in production, it may no longer be economical to keep a local breed (Tisdell, 2003).

Since countries are the responsible legal bodies not only for AnGR management and conservation but also for food security, national sovereignty over food security is important in discussions on flow of genetic material. Care must be taken to provide small farmers with the possibility for continuing and developing their activities, both for their own consumption and sale, and to provide them with the poultry genetic resources they need.

There could be a conflict of interest in achieving the goals of food security and agrobiodiversity: due to the high vertical integration and the economic efficiency of poultry breeding companies, a high ratio of commercial poultry in the total market supply makes it easier for countries to fulfil food security goals. It may be also easier to achieve food safety standards due to the ease of control of standardised production environments. Following economies of scale, governments may be tempted to spatially concentrate their veterinary or other livestock services around large scale production, leading to a decline of services that are directed to small producers. The highly integrated nature of the commercial poultry sub-sector, that also provides services, may even motivate the governments to pull out from service supply. Environmental concerns may also influence structural changes. Poultry production in Malaysia is expected to relocate from the present farming areas to more remote areas because of rapid urbanization and the need for large-scale operations. Poultry housing and poultry farms in general will have to become more environmentally friendly and poultry products will have to meet sanitary requirements (Malaysia Country Report (CR). The recent outbreaks of infectious diseases such as Avian Influenza may also have policy and structural implications. One option would be the favouring of production systems where biosecurity measures can be easily adopted. It seems that a focus on large scale production and increased biosecurity measures are favoured by exporting countries such as Thailand (Poapongsakorn, 2004). Another option would be the recognition of the disease reservoir existent in backyard chickens, mainly composed of local breeds, while encouraging vaccination and better health care. Also, extended breeding of chicken in community poultry farms may help to avoid the introduction of the virus and may also help prompt reporting of diseases (Dolberg, 2004).

The effects of Avian influenza outbreaks in Asia on specific production systems and identification of most affected breeds is still to be determined, but there are concerns about the loss of local genetic resources, particularly in fighting breeds (Poapongsakorn, 2004; Dolberg, 2004). Another issue for investigation is whether standardized systems with specialised single breeds differ from mixes of multipurpose breeds in variable environments with regard to vulnerability and flexibility to changes.

Breeding of local poultry

Erosion of local poultry genetic resources and intensive use of high productive lines both occur in the poultry sector. Hard data on the superiority of local breeds with regards to adaptation and disease resistance are scarce and research is needed. There is still a lack of information about existing or potential levels of productivity, production characteristics of local breeds managed under extensive systems, of the genetic make-up of the indigenous chickens, and insufficient knowledge of the most suitable exotic breeds and breeding strategies. The diversity in breeds, feed resources and management systems makes it difficult to develop strategies for improvement which are of widespread applicability. The task is to identify such breeds, and to determine variability within and between them. The little research that has been undertaken found that there are highly productive indigenous birds (Mathur *et al.*, 1989; Nwosu, 1979). According to Horst (1988), the genetic resource base of the indigenous chickens in the tropics is rich and should form the basis for genetic improvement and diversification to produce a breed adapted to local conditions. The selected birds can then be used for crossing to improve production further. However, apart from the Fayoumi breed developed in Egypt (Hossary and Galal, 1995), there appears to be no record of a tropical adapted breed developed from indigenous chickens in Africa. Fayoumi has been introduced in countries such as Tanzania (Katule, 1989), Ethiopia (Swan, 1996) and Bangladesh (Jensen, 1996).

A major global thrust on genetic preservation and biodiversity is reflected in efforts on development of genome and data banks (Crawford, 1989; Gunawan, 1989; Henson, 1992; National Research Council, 1993; Crawford and Gavora, 1993; Boa-Amponsem *et al.*, 2004; Hoffmann *et al.*, 2004). These initiatives are timely because continued cross-breeding programmes in rural poultry which do not consider gene preservation aspects leads to erosion of the indigenous germplasm (Bessei, 1989). As shown in the country reports, countries' awareness of the cultural and option value of PoGR is increasing, and measures are taken to halt genetic erosion.

Countries employ different strategies to develop their commercial poultry sector and their local poultry genetic resources. China, besides stimulating the industrial sector, has put strong focus on characterisation and description of local breeds, and on conservation programmes (China CR). Besides the upgrading and crossbreeding programmes mentioned above, only few examples of breeding programmes with local poultry are mentioned in the country reports. Sri Lanka has created lines of layers and broilers based on local chicken (Sri Lanka CR).

Countries' attempts to build up their own breeding industry are impeded by two factors: Competition with international poultry breeding companies and the lack of local poultry breeds suitable for modern commercial production. A good example was reported by Finland concerning the demise of the local commercial poultry breeding industry. After the opening of borders and lifting of trade restrictions, it took the international breeding companies three years to take over the full supply of the laying hen breeding market in 1987 (Finland CR). In Latvia only 15 specialized farms remained from the Soviet era, and only imported parent stocks are used for industrial poultry production. Industrial poultry with its high specialization have reduced the importance of the locally adapted breeds. With no locally adapted breeds left in appreciable numbers in Latvia, and no pedigree poultry farms, there is no information available showing if any breed could be of interest and utilized in an industrial setting (Latvia CR). A similar situation was experienced in Ukraine, where the high concentration and specialization of chicken production has resulted in sharp decline in inventories of native breeds (Ukraine CR). In Malaysia, there are no local poultry breeds suitable for modern commercial production. The breeds introduced and continually supplied by international breeding companies are, however, of utmost importance in terms of contribution to food security and agricultural production (Malaysia CR).

Conclusion and outlook

In many developing countries, the local gene pool still provides the basis for the poultry sector. The genetic resource base of the indigenous chickens could form the basis for genetic improvement and diversification to produce breeds adapted to local conditions. However, breeding programmes for local chicken will be difficult to set-up because of the competition with the commercial breeding companies which have access to technology advantages and economies of scale. Therefore, the future of local chicken in developing countries is uncertain. There are, however, some ways in which traditional poultry keeping can benefit from the intensive sector: through disease control and vaccination, mainly against Newcastle disease to reduce losses, and improved nutrition to ensure better quality products (Brankaert, 1996; Alders and Spradbrow 2001; Guerne-Bleich *et al.*, 2004). Newcastle disease is the most important health problem while breeding, feeding and marketing constraints also need high attention. A co-ordinated programme involving breeding, feed, health management was suggested for the development of family poultry production (Sonaiya *et al.*, 1999).

In developed countries, a large number of breeders contribute to conserving their traditional fancy breeds. There is an effort to maintain in vivo the reserve lines from companies or university research lines that are no longer needed, particularly in the USA and Canada, although financial resources are becoming less available for these initiatives. This is not an affordable solution for developing countries. Decisions are called for from governments and from the private sector in terms of setting goals and priorities for the conservation of PoGR.

It is clear that national policies need to consider a variety of trade-offs and need to define their position along a spectrum of options between two extremes such as public *vs.* private investment, large scale *vs.* small scale farming, formal *vs.* informal sector, economic growth *vs.* equity, job creation *vs.* self-employment, food security *vs.* agrobiodiversity, standards and food safety *vs.* food diversity. National and international policies need to identify their objectives and take decisions regarding the maintenance of breed diversity and genetic variability. This will have implications on breeding and conservation methods and the subsequent funding required. It also has implications on the research and technologies for characterisation and valuation needed. Public-private partnerships are needed to achieve most objectives. Overall, there is an urgent need to raise awareness of the value of PoGR for food and agriculture, and for advocacy at all levels.

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