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RECENT TRENDS IN THE GLOBAL ORGANIZATION OF ANIMAL BREEDING

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INTRODUCTION

The livestock sector is globally an increasingly important contributor to economic development and food security but not always recognized to be so by policy makers; especially in developing countries. Public investment in the livestock sector in developing countries is usually found to be inadequate or even non-existent in areas such as breeding programmes where it is extremely necessary. In developing countries, the demand for livestock products is increasing fast due to increasing population, income and urbanization while it is stagnating in developed countries. Breeding programmes in developed countries have started to emphasize more the goals of increased efficiency, improved animal welfare and environmental sustainability (Thornton, 2010). The world livestock sector has expanded rapidly over the past two decades, supported by technological and structural change. The surging demand for livestock products has led to the establishment of large commercial livestock production operations and associated food chains while there are still millions of rural people keeping livestock in traditional systems to earn their livelihoods. Supply-side factors, such as the globalization of supply chains for feed, genetic stock and other technology, are further transforming the structure of the sector (FAO, 2009). Indigenous cattle, buffaloes, small ruminants, pigs and poultry in developing countries have, however, largely remained outside the purview of systematic genetic improvement.

This paper first describes the general outline of animal breeding programmes. Subsequently, it presents the increasing concentration in developed countries of poultry, pig and cattle breeding programmes in a few multi-national companies and the general absence of effective genetic improvement programmes in developing countries. The need to convince livestock keepers, civil society organizations and policy makers in developing

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and developed countries of the importance of livestock breeding programmes for poverty alleviation is emphasized.

CONSUMPTION AND PRODUCTION TRENDS OF MAJOR LIVESTOCK PRODUCTS

The per capita consumption of eggs, meat and milk increased significantly in developing countries (except sub-Saharan Africa) from 1980 onwards. This is still, however, substantially lower than in developed countries. Production of these commodities over the same period also increased greatly in developing countries and more modestly in developed countries. Overall, egg production increased 150%, milk production increased 44% and meat production more than doubled. China and Brazil showed the highest growth in meat production; egg production increased the most in east and south-east Asia while India showed the largest increase in milk production (FAO, 2009). A large part of this increase was due to increased productivity per animal which in turn was brought about by genetic improvement mainly in broiler, egg, pork and milk production. Most of the increase in meat production was from monogastrics; poultry meat production was the fastest-growing sub-sector, followed by pig meat production. Pig meat accounts for over 40 percent of global meat supplies, poultry meat for 26 per cent and meat from cattle and small ruminants accounts for the remaining 30 per cent.

In general terms, aquaculture can also benefit the livelihoods of the poor either through an improved food supply or through employment and increased income. However, aquaculture species are not included in this paper.

ANIMAL BREEDING

We know of several definitions of animal breeding in the scientific literature, since the initial one of Jay Lush in 1945: "the means available for improving the heredity of farm animals". Ollivier (2000) gave a single phrase that encompasses the breadth of the discipline, “animal breeding may be seen as the optimal exploitation of the species' *biological variation*, under given constraints of *reproductive capacity*, using appropriate *breeding value* estimation tools”. "Optimal" in this definition implies some defined criterion of optimality. The term *genetic improvement*, often considered as synonymous to *breeding*, also implies that something better is being looked for.

Breeding schemes aim at utilisation of the between and within breed genetic diversity. Breeding schemes are not aiming at a fixed target; breeding organisations are dynamically searching for improvements. Differences in economic, social and ecological production environment give rise to different desired directions of change. The desired direction of change of a particular breed might differ between regions and change over time. Changes over time are strongly driven by needs of consumers and society. Breeding organisations are increasingly aware of this and are changing their breeding objectives by including traits related to animal welfare and quality of product. Reproductive capacities of animals put a major constraint on any animal breeding operation. Reproductive techniques like artificial insemination and embryo transfer can be used to overcome these constraints. These techniques play an important role in the activities of breeding organisations. In essence, the most basic effect of reproductive technologies is to increase fecundity. This means that fewer parents are needed to produce a given number of offspring. The application of reproductive techniques has had a major impact on the structure of breeding programs, the rate of genetic gain and the dissemination of genetic gain in livestock production.

BACKGROUND ON BREEDING SCHEMES

Two activities need to be distinguished in animal breeding programs. The first is the generation of genetic improvement by selecting animals based on their estimated breeding value for the relevant traits. Secondly, there is the dissemination of superior genetic material from the nucleus to the commercial population. The genetic improvement is generated in a small fraction of the population (referred to as nucleus animals). In pigs and poultry, closed nucleus schemes are generally used in which nucleus animals are kept on a small number of farms and only animals from these nucleus farms can contribute to genetic improvement of the nucleus population. In dairy cattle, open nucleus schemes are used, i.e. commercial and nucleus cows are eligible for selection as parents for the next generation of nucleus animals.

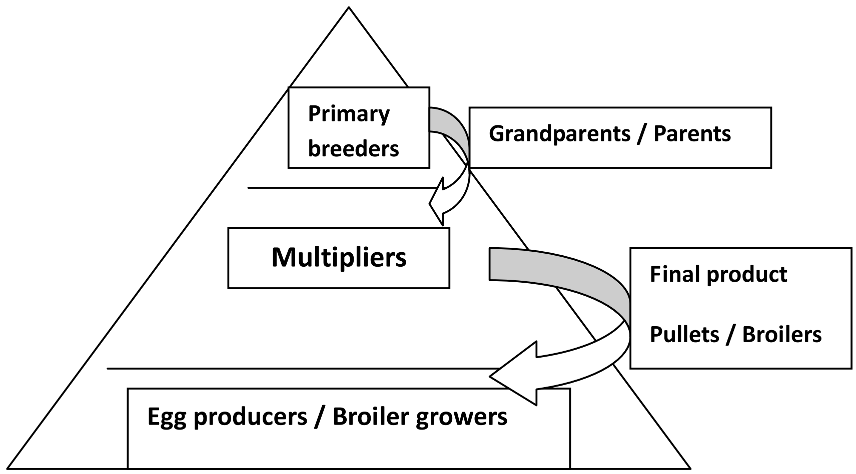

Fig. 1. The hierarchical structure of the global poultry industry

Hierarchy with different distinct tiers is best illustrated when looking at the modern poultry industry (Figure 1). Primary breeding is highly specialised and involves considerable investments in facilities and human resources to generate competitive rates of genetic progress over a long period of time while preserving genetic variation and maximising biosecurity. Europe is the main source of the world's poultry breeding stock. Continuing concentration has led to the current situation that only three groups of primary breeders account for about 90% of the layers, broilers and turkeys produced annually. Most breeding companies offer several different strain crosses to satisfy a range of customer demands.

GENETIC PROGRESS

A breeding scheme aims at genetic improvement in the breeding goal through the selection of parents to produce the next generation. The breeding goal reflects the combination of traits that the breeder aims at improving through selection. The amount of genetic improvement in the breeding goal (and the underlying trait) depends on the accuracy of the selection criteria, the intensity of selection and the generation interval (e.g. Van Arendonk and Bijma, 2003; Van Arendonk, 2010).

The accuracy of selection depends largely on the quality and the number of performance records that are available. Genetic improvement can only be made if performance and pedigree on animals in the population are available. Based on these observations, the genetic merit of an individual for the defined breeding goal can be predicted and the animals with the highest predicted merit can be selected as parents. In the past, selection for improved health of dairy cows, for example, has been seriously hindered by the lack of records of the health status of animals. This problem can be overcome by keeping all potential breeding animals on a small number of centralised herds with a more detailed performance recording. In pig and poultry breeding, breeding schemes are based largely on information collected on a small number of centralised herds. In dairy cattle, breeding schemes in developed countries have capitalised on the widespread use of on-farm milk recording schemes. The schemes collect information on milk production, fertility and conformation traits but -except for the Scandinavian countries- not on health traits.

The selection intensity reflects the proportion of animals that are needed as parents for the next generation. Reproduction techniques have an important influence on the number of parents that are needed for the production of the next generation and thereby on the rate of genetic improvement. In cattle, the introduction of artificial insemination has resulted in an enormous reduction of the number of sires and contributed to the exchange of genetic material between regions and countries. Due to the high reproductive rate of sires, the selection of bulls contributes 70% to the total genetic change in dairy and beef cattle populations. In sheep and goat production, artificial insemination is used but the impacts on reproductive rate are much smaller. In a population, only a small fraction of the animals do have an impact on the genetic improvement (these are generally referred to as nucleus population). In dairy and beef cattle, the bulls used for artificial insemination and the cows with high genetic merit are the nucleus animals and they form less than 1% of the entire population. Selection in this nucleus population creates the genetic progress in a population. The genetic progress generated in the nucleus is spread to the general population through the exchange of animals. Through artificial insemination, bulls selected in the nucleus are used in the general population. In sheep and goat breeding, this exchange of genetic material largely depends on the trade of live animals. Reproduction technologies (such as artificial insemination) can be used for generating as well as disseminating genetic material but their roles might differ. For example, embryo transfer plays an important role in generating genetic progress in dairy cattle while its role in dissemination is limited (Van Arendonk and Bijma, 2003).

An example given by Flint and Woolliams (2008) illustrates the significant value added by selective breeding if it is done systematically and scientifically. "A conservative estimate of the annual value of livestock production in Europe is €123 billion. Annual genetic gain in the livestock industry at the producer level is 1.5% or €1.8 billion. The annual research and development cost of breeding organizations, including collecting data for estimating breeding values and carrying out breeding programmes but not product marketing, is approximately €150 million, a benefit to cost ratio of 10." Genetic gains are permanent and cumulative so that the gain made in one year will give benefits over all subsequent years without further intervention. The livestock sector in Europe employs 3.5 million people and remains the largest sector in agriculture in terms of both employment and output value. Genetic progress is therefore central to the success of this major industry.

Rate of Inbreeding

Maintenance of biodiversity is an important element of sustainable animal breeding and reproduction. The loss of genetic diversity within a breed is related to the rate of inbreeding (ΔF). Genetic variation is lost by genetic drift and gained by mutation and therefore the minimum population size to maintain genetic variation is a function of mutation rate (Hill, 2000). The magnitude of inbreeding at the population level is measured by the rate of inbreeding (ΔF). Only in the absence of selection ΔF is related directly to the number of sires and dams. In selected populations, this equation is no longer valid because parents contribute unequally to the next generation (Woolliams et al. 1999; Woolliams and Bijma, 2000). Research on optimisation of breeding schemes has initially focused on genetic gain while little attention was paid to inbreeding (i.e. longer-term consequences of selection for genetic diversity). However, it is now well accepted that an evaluation of alternative breeding schemes should be based on genetic gain while constraining inbreeding.

Species-wise organization of breeding

Poultry

The modern poultry industry has a typical hierarchical structure with several distinct tiers (Fig. 1). Poultry was mostly bred privately by a multitude of breeders, until a concentration process set in between 1989 and 2006 which led to just four companies (reduced from 11) supplying the global markets for broilers, two for layers (reduced from 10) and three for turkeys (Gura, 2008). The companies own and genetically improve the pure-line breeding populations.

Breeding companies which are corporations based mainly in Europe and North America, with subsidiaries in major production regions, own the pure lines. Hatcheries (multipliers) are located near population centres around the world. They receive either parents or grandparents from the breeders as day-old chicks, and produce the final crosses for producers (FAO, 2007). Poultry breeding companies develop different lines for different markets and production environments. Breeding companies are large in the sense of market share but some multipliers have much larger turnovers than breeding companies. The specialized breeding sector has become highly competitive. Many companies go out of business due to their inability to survive the competition or are taken over by other companies.

The Venkateshwara Hatcheries (VH) group in India, with a large share of the Indian market has developed layer and broiler hybrids adapted to tropical climate and management conditions using parent lines from the world's leading companies by forming joint ventures with them (http://www.venkys.com). Around two thirds of the world's broiler and half of the world's egg production are industrialized (Gura, 2007). The slowly but steadily growing global organic sector has problems to find poultry strains adapted to its production systems. An exception to this is Label Rouge production system in which slow-growing breeds are used to meet the slaughter age of 81 days.

PIGS

The pig sector also has a pyramidal structure but the level of concentration is less than in the poultry industry. Some cooperative companies of pig breeders such as Topigs are involved in breeding. There are more breeding companies in the pig sector than in poultry although a few of them have large market shares such as PIC. As in poultry, the organisations involved in genetic improvement have world wide distribution networks. Compared to poultry breeding, the number of breeders, i.e. people owning male and or female animals, is much larger in pig breeding. Vertical integration from genetics to pork products is high in North America, and fast growing in many European countries (Gura, 2007). Commercial producers buy both sows and boars of specialized lines or crosses from breeding companies and crossbreed them to produce pigs for slaughter. Artificial insemination (AI) is used in the pig industry. In contrast to poultry, there are still breeding associations for pigs in many countries. Additionally, national genetic evaluations, mainly at the pure-breed level, are performed in many developed countries (e.g. by the National Swine Registry in the United States of America) (FAO, 2007).

In pigs and poultry, a typical breeding programme involves a number of sire and dam lines. Increasingly, nucleus breeding stock of these lines is centrally owned by breeding companies producing crossbred breeding stock for commercial producers. From a genetic point of view there are three reasons for the use of crossbreeding in pigs and poultry, viz. (1) female reproductive rate, (2) heterosis for relevant traits and (3) the possibility of combining specialized lines to meet the demand in different markets. Breeding companies can protect their ownership of elite genetic material by only selling one sex per line at the grand parent or parent level and crossbred stock to commercial producers.

DAIRY AND BEEF CATTLE AND BUFFALOES

There is a more complex and more open organizational structure in the cattle breeding sector with more input from government agencies than in poultry or pig breeding (FAO, 2007). Cattle breeding programmes tend to be more country-specific. However, superior genetics is globally distributed mainly through frozen semen and - to a lesser extent - through embryos. Cattle breeding companies are also moving towards mergers and expansion such as Genus (U.K.) merging with ABS Genetics (U.S.A.) to supply dairy and beef cattle genetics to over 70 countries. In a typical dairy cattle breeding programme, pedigree information is often recorded, owned and managed by breed societies, while milk production records are owned by farmers, but collected and managed by milk recording organizations (FAO, 2007). International genetic evaluations of bulls are being coordinated by the International Bull Evaluation Service (Interbull) in Sweden since the 1990s.

Exports of North American Holstein genetics increased steadily from the 1970s into the 1990s because of the perceived superiority of North American Holsteins for dairy traits compared with European strains, especially for production. The extensive exchange of elite genetics has led to a global dairy genetics industry with bulls that are closely related, and the average inbreeding level for the major dairy breeds continues to increase (Funk, 2006). Selection emphasis in dairy cattle is moving away from production traits and towards functional (mainly health and fitness) traits. This change started in Scandinavian countries but other countries have started to follow them. Since 1974 functional traits as fertility and health have been included in the Norwegian breeding program with dairy cattle. In the beginning the weighting on these traits was rather low, but it was substantially increased from 1980 to 1990 (Groen *et al*., 1997).Fertility has become the major breeding and management issue facing dairy farmers today.

There are a few government progeny testing programmes of Murrah and Mehsana buffaloes in India but their impact on genetic improvement has not been estimated. Generally there are no systems in place to exploit the genetics of superior animals with farmers in India.

Sheep and goats

There are only few large breeding corporations in the sheep and goat sector. Extensive grazing rather than stall feeding is still the norm for sheep and goats. Major breeding programmes for fine-wool sheep, based on straight breeding, are mainly found in the southern hemisphere (Australia and New Zealand). There are some large sheep studs in these countries that supply rams widely. The stratified sheep industry in the U.K. based on crossbreeding is a well-known example (Simm, 1998). It functions on the basis of a loose structure involving several breed societies, government agencies and other institutions. In this system, genetic improvement efforts are concentrated mostly on terminal-sire breeds. Most dairy goats are in developing countries but without a well developed breeding structure. Breeding programmes for goats are concentrated mainly in Europe and North America. There are a few small institutional closed nucleus flocks of some sheep and goat breeds in India. The French selection programme, based on AI with frozen semen and oestrus synchronization (60 000 goats inseminated/year), and the Norwegian programme, based on rotation of sires in several flocks (buck circles), are examples of organized progeny testing programmes (FAO, 2007).

Despite the large numbers and importance of adapted indigenous sheep and goats in the tropics, information on sustainable conventional breeding programmes for them is scarce and often unavailable (Kosgey *et al*., 2006). Dismal performance of programmes involving breed substitution of exotics for indigenous breeds and crossbreeding with temperate breeds have stimulated a recent re-orientation of breeding programmes in tropical countries to utilize indigenous breeds, and most programmes are incipient. Kosgey *et al*. (2006) concluded that the success rate of some breeding programmes involving native breeds is encouraging. Definition of comprehensive breeding objectives incorporating the specific, immediate, and long-term social and economic circumstances of the target group as well as ecological constraints was found lacking in some projects that failed. To achieve success, it is necessary to look at the production system holistically, and involve the producer at every stage in the planning and operation of the breeding programme, integrating traditional behaviour and values.

Impact of genomic selection and other technological developments

Genomic selection (GS) may be defined as the simultaneous selection for many (hundreds of thousands of) markers, which cover the entire genome in a dense manner so that all functional genes are expected to be associated with at least some of the markers (Meuwissen *et al*., 2001). Large breeding companies are well-placed to start using GS and other modern technologies. DNA information allows the estimation of relationships among animals where pedigrees are not recorded. This aspect makes genetic marker technology attractive to developing countries as it virtually means an opportunity to start a genetic improvement programme in an unpedigreed population if performance records are available (van Arendonk, 2010). Extensive validation of the association between genotypes and phenotypes will, however, be needed before GS can be implemented. Large scale genotyping of animals without such validation or efficient data analysis is likely to result only in wasteful expenditure without any real improvement.

BREEDING PROGRAMMES IN LOW INPUT SYSTEMS

There are 640 million smallholders and 190 million pastoralists in the world who raise livestock of mainly local breeds for their livelihoods (Gura, 2008). They usually do not get the benefit of any organized genetic improvement for the local breeds they rear although they have established methods of selection for their preferred breeding objectives. Their breeding criteria are often many more and more varied than the narrow production criteria of industrial systems. Within-breed improvement programmes can contribute to improved livelihood of livestock keepers who depend on low-input systems if they are compatible with the production system and the needs of the smallholders. Some examples of community based breeding programmes are the llama breeding programme in Ayopaya, Bolivia, the Boran cattle breeding programme in Kenya and the breeding programme for local pig breeds in north Viet Nam (FAO, 2007). Developing country governments mostly seem unaware of the necessity of livestock genetic improvement programmes and apathetic to investing in such programmes. It therefore remains to the livestock keepers to establish community-based breeding programmes. However, this requires appropriate and adequate institutional structures. The high level of awareness created throughout the world and at all levels of society in recent years about the vital importance of the conservation of animal genetic resources needs to be carried a step further to encompass the importance of livestock genetic improvement. Livestock keepers, civil society organizations and policy makers need to be convinced that establishing and running breeding programmes effectively would contribute to poverty alleviation and economic development.

CONCLUSIONS

The increased availability of cheap livestock products to the growing world population has become possible due to modern developments in livestock breeding and management. Organization of poultry, pig and cattle breeding is becoming highly concentrated in a few international breeding corporations with its associated dangers. Policy makers in developing countries need to be convinced of the importance of investing in livestock genetic improvement so that smallholder livestock farmers and pastoralists can adapt better to the rapid changes in their production and marketing circumstances.

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