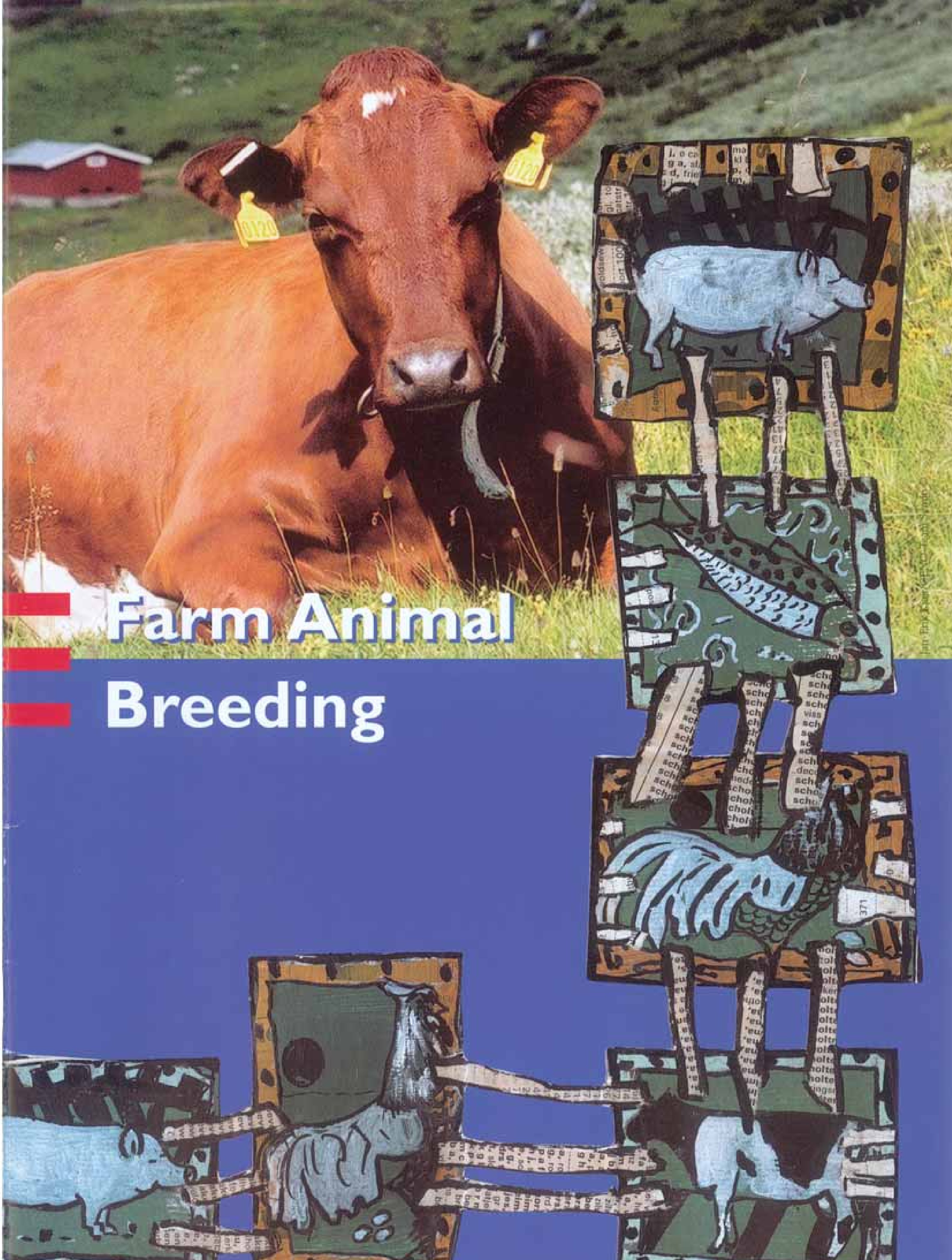

Farm Animal Breeding

What is Farm Animal Breeding?

Farm animal breeders improve livestock by selecting animals with desirable traits and breeding from them. This simple activity is capable of bringing about significant change — as can be seen from the fact that the Chihuahua, at barely a kilogram, and the Irish Wolfhound, at over a metre tall, are both selectively bred descendants of the wild wolf. Importantly, for modern breeders, it can also be used to modify less obvious characteristics, such as fertility, longevity and health.

Selective breeding is probably as old as farming itself, but in the mid-nineteenth century breeding began to emerge as a distinct activity in the agricultural sector. At this stage, animals were mated naturally, and selection was based on appearance and performance. What was new was the tracing and certification of breeds in herd books.

Today natural siring is still used in sheep and goats, but in cattle and pigs artificial insemination has become routine. In North European countries, embryo transfer is used in cattle. Performance data on an animal's kin are also called upon to forecast its breeding value; and genomics enables the breeder to select for specific traits using information about the genes themselves.

Livestock breeding involves two distinct phases. Breeders must first **breed** (i.e. select and mate) animals with desirable features, and then ensure that those animals **reproduce** and pass on the features to large numbers of farmed offspring.

Methods of selection and reproductive techniques have become very much more powerful and refined over the last fifty years. As a result, animal breeding continues to make highly cost-effective contributions to the livestock economy.

On the other hand, the traits selected for today are more complex and varied than they once were. In the past the primary goal of breeding was greater productivity — faster growing broilers, cows that produced more milk, beef cattle with more muscle and so on. Nowadays, however, Western consumers often look for an assurance that animal food products are safe to eat, nutritionally rich and of high gastronomic quality. Some prefer foods made from local or rare breeds of animal; others only eat products from ethically farmed animals. Over the coming decades, farm animal breeding will play a crucial role in the efforts of the food sector to satisfy these differing consumer demands.

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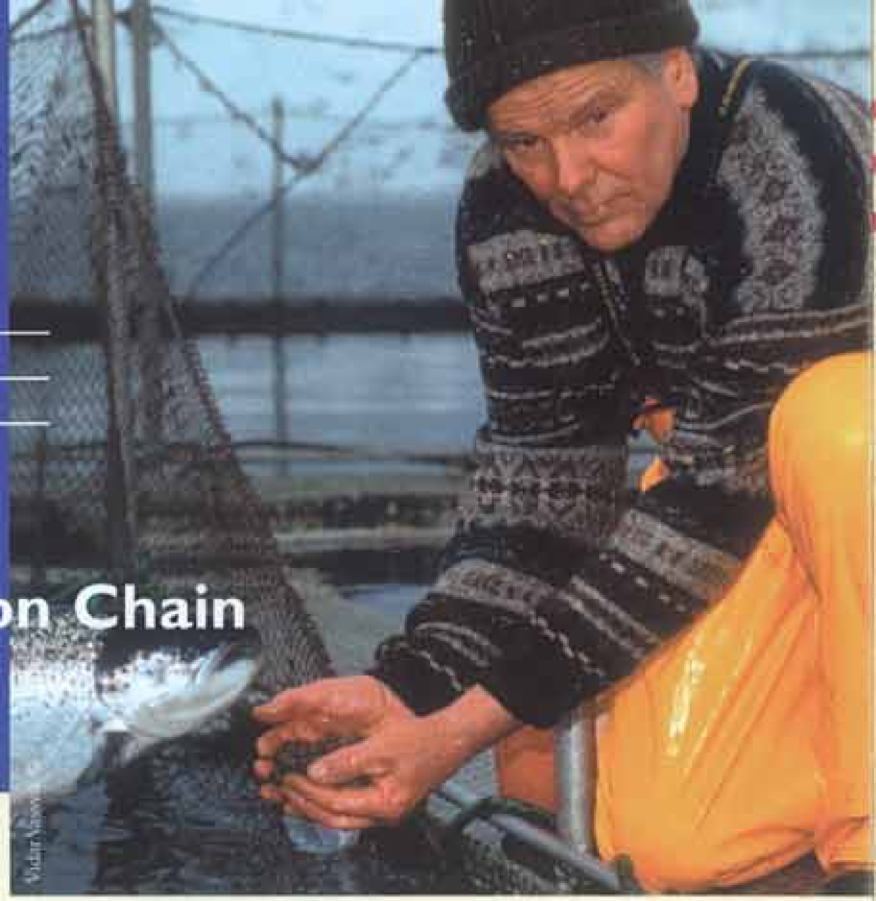
'Selective breeding is probably as old as farming itself.'

'Breeders allow the food sector to meet consumer demands.'



2 The Food Production Chain

Farm animal breeding is the first stage in a production chain with four tiers:

Retail of animal products
milk, cheese, meat cuts, wool etc. purchased by consumers

Processing of animal products
in dairies, slaughterhouses etc.

Farming of animals
animals raised and milked, sheared and fattened etc.

Breeding of animals
improved dairy cows, broilers, pigs, etc.

Ultimately, the purchasing behaviour of consumers overwhelmingly dictates activities in each of these sectors.

Throughout the developed world, twenty-first century consumers seem to be responding to several basic factors when shopping for food. First, they look at **cost** and aim to spend prudently. Second, they display an increasingly sophisticated awareness of the long-term **health** implications of diet. Third, with rising levels of prosperity, the gastronomic **quality** (e.g. flavour and texture) of cooking ingredients and ready-made foods has grown in importance. Fourth, in the wake of recent 'food scares' arising from BSE, salmonella and so on, many people now monitor the **safety** of what they eat. And fifth, particularly in Northern Europe, there is widespread concern about the **welfare** of farm animals.

Breeders allow the food sector to meet these consumer demands. Wherever the contributions of breeding and farming practices to long-term livestock improvement have been separated, genetic changes resulting from breeding have been shown to contribute the lion's share of the better performance. Certainly, much recent progress on the cost, healthiness and gastronomic quality of animal food products has been made on the bottom tier of the model above.

It is true that advances in food safety and ethical acceptability are often made through better procedures in abattoirs and factories, and raised standards of husbandry. But even here, farm animal breeders have made real contributions. Thus dairy cattle with lowered susceptibility to mastitis have been bred, and reproductive technologies like AI and embryo transfer help to prevent diseases spreading.

3 Breeding Improved Animals

As mentioned above, farm animal breeding involves both breeding and reproduction. These processes are described in turn in this and the next section.

Modern breeding involves three steps.

- The definition of breeding objectives
- The selection of animals with traits that fit the objectives
- The mating of these animals

To define a **breeding objective** the breeder must identify traits, such as enhanced fertility or accelerated growth rate, that deliver improvements. This fixing of a direction of genetic change is the most challenging part of breeding. The 'direction' in which to move is seldom easy to determine. In developing food markets, traits that are urgently needed today may be unimportant tomorrow — and of course it is tomorrow for which the breeder must plan, since it can take years for breeding successes to percolate down to the supermarkets.

Even when the destination of genetic change is clear, it can be difficult to determine how best to get there. Breeders construct their objectives by adjusting the economic weightings of traits or introducing new traits. But they must be careful to ensure that the traits they prioritise are compatible and not too numerous. In dairy cattle, for example, lower milk fat and higher milk protein cannot be promoted at the same time: these traits are genetically 'intimate', and in practice they advance or recede together. Equally, where too many traits are sought, the breeder's efforts will be diluted and little progress will be made with each trait. Trade-offs and compromise are therefore an unavoidable feature of breeding design.

The second step is to **select** the animal, or variety of animal, that will best meet the breeding objectives when bred from. At this point 'selection indices' help to translate the objectives into practical selection decisions. These indices rank potential breeding animals according to their overall scores for several traits. In them, weaknesses in one trait can be compensated for by strengths in another.

In the simplest case, breeders determine whether an animal has a sought-after trait by examining the animal in isolation. This approach is feasible when the heritability of the trait is high — as is the case, for example, with body size. It is unsuitable for traits with low heritability (e.g. fertility traits) and for traits whose measurement would destroy the animal's ability to breed (e.g. traits manifest only in slaughter data).

Today, problematic traits can be identified in a variety of ways. In some cases, data gathered from relatives of the candidate animal are the guide. **Pedigree** data (from ancestors or collateral relatives) or **progeny** data (from descendants) are collected. Modern breeders feed data of these kinds into computers with sophisticated statistical software to generate selection decisions. In other cases, breeders use **genomics** — an approach directly exploiting information about an animal's genes.

None of these techniques involves **genetic engineering** or transgenesis, i.e. the creation of novel genetic combinations by direct manipulation of genes in the laboratory. In Europe, the focus of animal breeding at present remains selection, not creation. There is considerable consumer resistance to 'GM' farm animals.

The third and last step in farm animal breeding is to **mate** the selected animals to produce the superior variety of animal envisaged by the breeder. Here various mating systems are used. Mated individuals are of different breeds or lines in 'crossbreeding', the same breed or line in 'purebreeding', and close relatives (siblings, cousins etc.) in 'inbreeding'.

'Trade-offs and compromise are an unavoidable feature of breeding design.'

4 Supplying the Farms

'Embryos are even less likely to harbour transmissible diseases than semen'

The techniques described in the last section will be of little value unless breeders can provide farmers with the animals they have improved in large numbers. This is where reproductive technology enters the picture.

Natural mating is still used to multiply livestock, especially in beef cattle, sheep and goats. Sometimes indeed mounting is the only option, because local facilities do not permit more sophisticated technologies to be used. Reproductive technologies are now used very commonly, however.

At present, the most important reproductive technology is **artificial insemination,** or AI. This technique — in which semen is collected from adult males, sometimes stored or transported in frozen form, and injected into the uteri of fertile females — has completely transformed breeding over the last 50 years. It is used extensively in dairy cattle, turkeys and (in some countries) pigs. Its chief advantage is that it allows the genetically excellent male to rapidly sire a large number of offspring. Because the male and female animals do not have physical contact, AI also helps to prevent the spread of disease.

Embryo transfer also limits disease transmission — indeed embryos are even less likely to harbour transmissible diseases than semen. It is less widely used than AI, but it has been utilised in cattle for 20 years now. Embryos are harvested from superior donor females and implanted in surrogate mothers. They are sometimes frozen, which means that they can be widely distributed or stored for future use. And stored embryos, unlike semen, are whole organisms with the full complement of genes, so they can be used to preserve endangered breeds.

When it is combined with **superovulation** — a method of stimulating female animals to produce many more ova, and hence embryos, than they would naturally — embryo transfer enables the breeder to obtain progeny from the donor female at an accelerated rate. This is of great value to cattle breeders, because in cattle calving intervals are long and only one calf is born at a time.

A third method of multiplying improved animals is, of course, **cloning.** However, there are cost objections to the commercial use of this method, and in Europe societal opposition to cloning is strong.

Finally, mention must be made of two techniques that are used in fish farming, both of which harness naturally occurring processes. As male fish mature the quality of their meat deteriorates and their growth rate declines. **Monosexing** involves altering the temperature at which fish are raised so that the fish become outwardly female. In fish such as trout, monosex female fry will grow to commercial weight before maturation.

Triploidisation is also triggered by thermal treatment, although in this case the treatment generates fish with three sets of chromosomes instead of the usual two. Triploid fish are very useful because they cannot interbreed with and contaminate wild stocks if they escape. Also, like monosex fish, they have delayed maturation.

5 Ruminants, Pigs, Poultry and Fish

Until the 1950s, most breeds of ruminant — i.e. most cattle, sheep and goats — were multi-purpose. A single breed of cattle, for example, would be kept for both beef and milk. That same breed might even be kept for draught purposes, or for hides, as well. Over the last fifty years, specialisation has been the theme. In the main cattle are now bred either for meat or to produce milk, and sheep bred for their meat are generally distinct from those bred for their wool.

In another way, however, breeders are returning to **multiple objectives.** Quite often today, productivity — heavier bulls, higher milk yields — is not the sole selection criterion. Functional traits, such as disease resistance, fertility and longevity, are also sought. Trade-offs become necessary. For example, cows bred to be less susceptible to mastitis may have lower milk yields, but reduced veterinary costs can favour these cattle anyway.

In **pigs**, the twentieth century saw a move from purebreeding to crossbreeding. This encouraged hybrid vigour and allowed different selection pressures to be applied to male and female lines. Pig breeders once focused on traits with high heritability, such as overall growth and the development of backfat. Using computer technology, they have now turned their attention to more problematic traits, including litter-size and piglet vitality. Genomics may enable them to bring about improvements in traits, like disease resistance and pork quality, that are beyond the scope of traditional methods.

Turning to **poultry,** most eggs today come from specialist crossbred layer chickens. Broilers are also crossbred, solely for their meat. Slow-growing, high quality birds have been bred and are now marketed successfully in France under the 'Label Rouge' brand. The main selection criteria in poultry breeding remain productivity, product quality, the reduction of health and welfare problems (e.g. stronger legs in broilers) and traits sought by the processing plants, such as breast meat yield and uniformity of product.

Crossbreeding in poultry brings benefits. For example, production birds bred for meat (broiler chickens, turkeys and ducks) combine males lines selected for growth and uniformity and female lines selected for reproductive excellence. In the cross, hybrid vigour is also secured, and so the offspring have added vitality and productivity.

The **fish breeding** sector is still very young. Its programmes have rarely been running for more than seven or eight generations, and to date it has targeted a limited number of species of fish (trout, carp and salmon). In most countries contemporary fish breeding is similar to traditional cattle breeding, with selection being based on appearance and performance. Only in Norway are pedigree data available. On the other hand, the breeding gains here are 'just waiting to happen' — fish breeding is between two and three times more efficient in generating genetic change than ordinary terrestrial livestock breeding. The traits currently of interest relate to growth and, to a lesser extent, spawning season, age at maturation and shape.

'In another way, however, breeders are returning to multiple objectives.'

'Fish breeding is a rapidly developing sector.'

6 The Economic Impact of Breeding

There can be no doubt about the economic importance of the European livestock sector. Within the European Union, livestock farming generates approximately 60% of total agricultural output. In global terms, each of the sub-sectors of livestock farming is of major importance. If we put aside fish farming, which is currently a relatively small sector worldwide, the relevant EU figures are as follows: milk 22% of world production (the largest single share of the global market); beef 13% (second largest share); pork 19% (second largest share); poultry meat 13% (third largest share, after China and the USA); and chicken eggs 9% (second largest share, after China but ahead of the USA).

European farm animal breeders have played a crucial role in creating and maintaining these market shares. They have enabled Europe's livestock farmers to offer a wide range of competitively priced products — and in evolving food markets, the ability to offer varied products at reasonable cost is key to finding and keeping customers.

The pattern of national/international operation varies a good deal, as does the size and status of individual breeding businesses. **Cattle** breeders and **pig** breeders, for example, tend to be national farmers' cooperatives or SMEs. In **poultry,** breeding stocks are supplied by a few large-scale private companies: in chickens, turkeys and waterfowl, between two and four European companies per species provide 80-100% of the European market and up to 70% of the world market.

Fish breeding is a rapidly developing sector. Over recent years, a number of new companies have been set up, and already amalgamations are occurring. Globally, Europe is not the largest aquacultural supplier: that honour goes to East Asian countries, and in particular to China. However, two companies based in Europe provide the bulk of world breeding stock in Atlantic salmon (50-75%) and turbot (in excess of 75%).

The economic importance of this relatively modest number of companies is hard to overestimate. Genetic improvements brought about by breeding are **cumulative:** each cycle of breeding builds on the achievements of the last. They are also **permanent** in that, once a superior animal has been bred, no further breeding input is required to maintain the breed. And advances made by breeders can now be rapidly **disseminated** to a large number of livestock farmers. Reproductive technologies like AI permit an elite dairy bull, for example, to have tens of thousands of progeny in commercial herds across the globe during its lifetime. As a result of these features, breeding has strikingly impressive cost-benefit returns: it is expensive to do, but the returns are never less than 25:1 and in some species they can be 100:1.

7 Current and Future Trends

Markets for livestock products are developing in two directions at present: animal products tend to be destined either for 'quality' markets or for 'commodity' markets. Most European animal breeders work in both types of market. This requires strategic skill, since in many cases the imperatives within markets for commodities and quality goods are diametrically opposed.

In general, **quality** markets are highly differentiated, accommodate niche sub-markets and respond well to branding, image and product innovation. In quality food markets, consumers look at the healthiness and safety of products. Sales tend to be boosted by perceptions of food 'purity' and nutritional value, and fall in products with drug residues and additives. Price tends not to affect buying habits. **Commodity** markets are less differentiated and highly price sensitive. They exclude niche markets and are increasingly globalised. The foods sold in them are largely generic and admit of little innovation.

European breeders are responding energetically to these market pressures. Historically, their main goal has been to make livestock production more efficient, thus reducing the cost of foods. Efficiency has continuing relevance, particularly in commodity foods, where globalisation introduces an even greater need to be competitive. But today — especially, although not exclusively, in the quality markets — breeders are aiming to combine efficiency with other goals.

Food **safety** is being improved through the selection of animals with disease resistance traits. Food products from disease-free livestock are less likely to harbour residues of medication.

Breeders have been no less active in enhancing the **gastronomic quality** of food products — their taste, texture and aroma — in response to consumer demand. To give one example, pork from certain genotypes of pig was defectively pale, soft and exudative, but these genotypes have now been eradicated in breeding programmes.

Finally, for many years the breeding industry has worked to improve the **healthiness** of the foods we eat. Animals bred for their meat, for instance, have been selected to secure better fat-to-protein ratios. It is also anticipated that it will soon be possible to breed for nutritional traits. In Western nations, breeding outcomes such as these complement the efforts of the public health sector to reduce the incidence of diet-related health problems such as cardiovascular disease and cancer.

'Finally, for many years the breeding industry has worked to improve the healthiness of the foods we eat.'

Farm Animal Industrial Platform (FAIP)

Forum of European farm animal reproduction and selection organisations

Membership

Belgium: Gentec, Progenus. **Denmark:** Danish Cattle Breeding, Danske Slagterier (Federation of Danish Pig Producers and Slaughterhouses), Scanbrid. **Finland:** Finnish Animal Breeding Association (FABA). **France:** France Hybrides, Hubbard-ISA, Syndicat des Sélectionneurs Avicoles et Aquacoles Français (SYSAAF), Union Nationale des Coopératives d'Elevage et d'Insémination Animale (UNCEIA). **Germany:** Arbeitsgemeinschaft Deutscher Rinderzüchter, Lohmann Tierzucht, Schaumann Besitz-Hülsenberg, Zentralverband der Deutschen Schweineproduktion e.V.. **Italy:** Associazione Nazionale Allevatori Suini (ANAS), Semenitaly. **Netherlands:** Alta Genetics, CR-Delta, Hendrix Poultry Breeders (HPB), Intervet, IPG, Institute for Pig Genetics, Nutreco/Euribrid. **Norway:** Akvaforsk, Aqua Gen, Team Semin. **Spain:** Asociación Nacional de Criadores de Ganado Porcino Selecto (ANPS). **Sweden:** Svensk Avel. **Switzerland:** Arbeitsgemeinschaft Schweizerischer Rinderzüchter. **United Kingdom:** Aviagen, British Poultry Council, British United Turkeys (BUT), Genus, Sygen.

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