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INVESTMENTS IN BREEDING TECHNOLOGIES AND ORGANIZATION TO MEET GLOBAL NEEDS

J.A.M. van Arendonk, M.C.A.M Bink, K. Peeters, B. Visser, N. Duijvesteijn and P. van As

Hendrix Genetics, PO Box 114, 5830 AC Boxmeer, The Netherlands

SUMMARY

Animal breeding has a vital role to play in solving the global food challenge. This paper will concentrate on investments that are needed for animal breeding to meet the challenges of the future and begins with describing the global challenge. There is not a single solution that will work in all species in all regions, so solutions need to be tailored to the local conditions. There is a clear need for both more sustainable production of animal proteins and a reduction of waste in the food chain. There is regional diversity in emphasis on the different components of sustainability, but the general trend is towards animal protein production with a lower ecological impact, with a minimum use of antibiotics and with good animal welfare. This requires not only investments in genetic technologies like genomic selection but also in methods for phenotyping individual animals under commercial conditions.

INTRODUCTION

Animal breeding is a powerful tool to improve many aspects of animal production. In this paper, we describe the contributions of animal breeding to solving the global challenges when it comes to feeding the growing world population sustainably.

Hendrix Genetics is a multi-species animal breeding company with breeding programs in turkeys, layers, swine, salmon, trout, shrimp and coloured broilers. To be a competitive animal breeding company in any species requires substantial investments in research and development. By working in multiple species, these investments can be more cost effective as there are many similarities between species. For example, the IT infrastructure for collecting and storing information on individual animals and the methods for performing genomic evaluations are very similar for different species.

After a brief description of the global challenges and the expected changes in our value chains, we will describe in more detail the role of animal breeding and how new technologies can help to better meet the challenges.

GLOBAL CHALLENGE

We face major global challenges when it comes to feeding the growing world population sustainably. Rabobank has predicted that the animal protein market will grow by 45% in the next two decades and this global growth will be largely in Asia and to a lesser extent in Africa. We see more and more developing countries reaching middle income status, the inflection point for protein consumption, leading to an increased need for locally produced animal protein. The contribution of species to animal protein production differs between regions. For example, currently close to 90% of aquaculture production takes place in Asia, which is also the biggest growth market for layers and swine. In contrast, North America remains a high value and volume market for poultry, pigs and cattle, whereas aquaculture is expected to remain limited.

There is a clear need for more sustainable methods of producing all animal proteins. There is regional diversity in emphasis of the different components of sustainability, but the general trend is towards animal protein production with a lower ecological impact, with a minimum use of antibiotics and with good animal welfare.

At all levels in our value chains we see scale increasing. The number of people working in animal production is declining, the farms are getting bigger, and value chains are getting shorter and increasingly coordinated. Innovative farming methods using robotics and data driven management support will help not only to meet the labour challenge but also to improve sustainability.

Worldwide, the use of technology and software is rapidly increasing. Already thousands of companies offer data-based services to support farm management, increasingly making use of sensors, machine learning, and other decision-support tools. We also see increasing societal pressure in the developed world regarding environmental impact, livestock treatment and biotechnology. Also, large food companies and supermarket chains are forcing changes to production practices.

We anticipate the following changes in our value chains:

- Increased use of digital technology and software for managing farming operations, with large companies fulfilling this demand
- Increased mechanisation and automation, driving standardization
- Stronger presence of alternative sources of protein, including insects
- More and more varied animal protein "brands" differentiated by farming system, animal type, and product quality.
- More ready-to-eat providers, such as food delivery companies, and ready meals.

Animal protein production. There are many individuals on this planet who live relatively healthy lives consuming little or no animal protein, and many would argue that the challenge of feeding the human population could be met by reducing the amount of livestock products in our diet. However, the demand for animal protein, especially in developing countries, is expected to grow as they become more affluent. Part of the animals' proteins are produced from feed, such as grain, that could be directly consumed by humans, while another part is produced from feed resources that would not feed humans directly, such as grass and by-products from the human food industry.

According to the FAO, an estimated one third of all food produced globally is either lost or wasted. This represents a large inefficiency in the food system. Food loss refers to any food that is lost in the supply chain between the producer and the market. Food waste, on the other hand, refers to the discarding or alternative (non-food) use of food that is otherwise safe and nutritious for human consumption. Meeting the food challenge is not only about more sustainable production but also about reducing food loss and waste.

The challenge for livestock production is to meet the growing demand for animal protein while at the same time reducing the environmental impact. This implies that livestock production needs to improve the efficiency of production, robustness of animals and quality of animal products. Improvement of efficiency of animal production needs to focus on improving lifetime productivity, which can be achieved by improving not only individual productivity but also by reducing losses through improved health and reproductive performance. Robustness of animals refers to the ability of animals to handle variation in the environment, in particular feed quality and climate. The quality of animal products refers not only to the food safety and taste but also to animal welfare.

THE ROLE OF ANIMAL BREEDING

Animal breeding has a vital role to play in solving the global food challenge. In the last 4 decades, animal breeding has halved the amount of feed required to produce animal proteins in poultry and pigs. Reducing the ecological food print is an important contribution to improved sustainability. Improving sustainability also requires reducing the feed-food competition, reducing the use of antibiotics, and improving animal well-being.

Breeding goal. The breeding goal summarizes the direction of change of a population. Over the years, the breeding goal has changed in response to the changes in production circumstances and the increased attention to sustainability. Commercial poultry and pig breeding goals have broadened widely since the 1970s (Neeteson-van Nieuwenhoven *et al*. 2013). Over time, the relative focus on productivity has decreased and objectives such as efficiency, welfare, robustness and product quality have increased. Production circumstances and consumer demands will continue to change and impact the breeding goal not only in terms of the number of traits but also in terms of the relative emphasis.

Sustainability program: As a breeding company, we also keep many animals ourselves. That is why our efforts to achieving sustainability are not only directed towards our breeding program but also improving our own performance. For improving our own performance, we have established in 2013 a sustainability program comprising of three building blocks: animals, people and planet.

- Animal welfare, biosecurity and genetic resources are the key priorities within the building block animals. Ensuring animals are treated with care and respect and are kept under the highest standards of welfare is essential. We ensure that taking good care of animals is embedded in our company culture. As global suppliers of breeding stock, we have a responsibility for ensuring biosecurity and animal health. In addition, we also have an obligation to protect our genetic resources.
- People make our business and deliver our products and service to our customers. We started off with setting KPI's for health and safety including illness percentage, accidents and time lost time due to accidents. More recently, we have added employee engagement and expertise.
- Minimizing the environmental impact of livestock through improving input efficiency and helping to reduce the use of antibiotics are key parts of the building block planet. In addition, the company is investing in minimizing its own ecological footprint to preserve and improve the environment that its activities impact.

We have implemented a sustainability reporting cycle, which includes a regular program of data collection, target setting and evaluation which is aimed at making improvements year after year. In addition, we will publish a CSR report to increase the awareness on our activities both internally and externally.

DISSEMINATION

Not only generation but also dissemination of genetic progress plays an important role in an animal breeding organisation. In cattle, frozen semen is the most commonly used method of distributing genetic progress. In poultry and swine, frozen semen is not an option. In swine fresh semen and live animals are used for dissemination. In poultry hatching eggs and one-day old animals are used for dissemination. The use of live animals rather than frozen semen comes with logistic and biosecurity challenges.

In poultry and swine, a multi-tier crossbreeding system is used. In a typical laying-hen program, pure-line birds are used to produce grandparents which are crossbred to produce the parent stock males and parent stock females. The parent stock is used to produce the commercial birds as illustrated in Figure 1. The genetic progress is generated in the pure lines under bio secure conditions. Subsequently this progress is disseminated from the pure line to the commercial offspring through several multiplication steps. The system also allows capturing the benefits of crossbreeding. Furthermore, it allows making the best combination of different pure lines to meet the needs of farmers operating in different countries and markets. This system also offers the breeding organisation two options to react to a change in product demand and to a change in production environment. First, there is the option to change the combination of lines to produce the commercial product. Second, there is the option to change the breeding goal in one or more pure lines. By changing the combination of lines, we can react more rapidly to changes compared to changing the breeding goal of a line. We continuously evaluate the expected developments to ensure that the product portfolio not only meets the current needs but also the expected needs in the years to come.

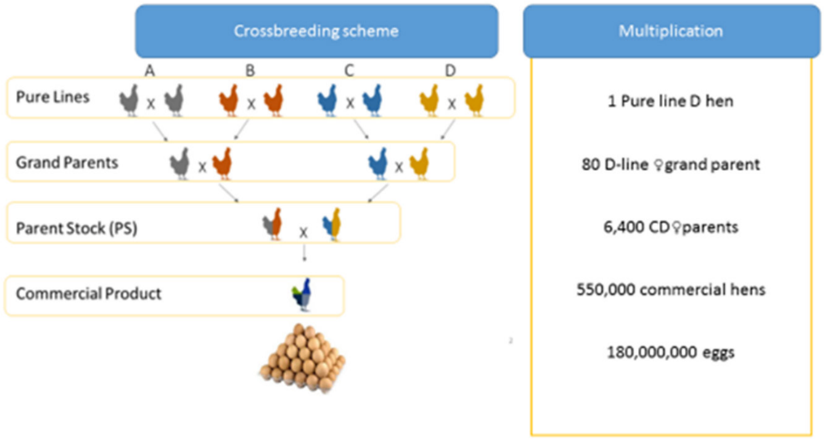

Figure 1. Schematic diagram of the poultry production pyramid in which genetics of 4 pure lines (A, B, C and D) is used in a crossbreeding scheme to produce parent stock (PS) males (AB) and females (CD) and commercial products (ABCD). The relative size (multiplication) of each layer in the production pyramid is given for the female lineages (from pure line D hen through grandparents and parents to commercial hens and eggs produced by these hens)

TECHNOLOGIES

Our future is tied directly to product superiority, which requires the implementation of state-of-the-art breeding technology for all our products. This implies that we invest in tools for collection of information on individual animals, in genomic selection to ensure that we make best use of the collected information and breeding scheme design. Investments in technology should also provide solutions for labour shortages on our breeding farms and on the farms of our customers.

We see many promising developments in the domains of phenotyping, digitalization, and genetics technologies. We will continue to make targeted investments in the most promising technologies starting from a business needs perspective. In the following sections, more background is given on activities in the domain on phenotyping and gene editing.

Phenotyping. We invest in phenotyping methods not only to collect novel traits in the domain of animal behaviour but also to measure performance of animals under commercial conditions. Remote sensors such as cameras, microphones, thermometers and accelerometers offer the opportunity to capture data from groups or individual animals. Data from remote monitoring sensors combined with individual animal identification can provide information regarding pig welfare, health and productivity (Benjamin and Yik 2019).

Livestock are nowadays more frequently kept in larger groups, resulting in an increase in social interactions between individuals. Moreover, treatments to limit the consequences of adverse social interactions, such as beak trimming in poultry and tail docking in pigs, will probably be banned in the future (at least in EU countries), so that the negative effects of social interactions will likely increase unless action is taken to avoid that. Actions are needed to prevent or diminish the negative effects of social interactions. Bijma (2007) demonstrated that pecking in laying hens is a socially affected trait which not only depends on the hen's ability to avoid being pecked (direct genetic effect) but also on the pecking behaviour of her group mates (indirect genetic effect). Using this knowledge, we have demonstrated that we can select animals that are less likely to perform damaging behaviour. Selection can be further improved using sensor technologies that allow the identification of laying hens in large groups that show less pecking behaviour (Ellen *et al*. 2019).

Traditionally, egg production on laying hens is measured in single bird or family group cages. This housing system is needed to link the egg production to a single individual or parent. The housing system, however, does not reflect the commercial conditions for laying hens which are increasingly kept in cage-free conditions. The difference between selection and commercial environment might lead to genotype by environment interaction which would make selection less effective. To overcome this, we are investing in automatic nests for laying hens which allows the recording of individual egg production of animals kept in a group. These automatic nests are not available on the market and need to be developed internally.

Gene editing is a rapidly developing technology with many potential applications, including in animal breeding. Hendrix Genetics is committed to responsible farm animal breeding. We strive to meet growing global demands for food by supporting animal protein producers worldwide with innovative and sustainable genetic solutions. New technologies like gene editing can be part of our future solutions. Alongside delivering benefits to producers, our solutions must also meet the rigorous needs of consumers and society.

While we rely on genomic selection in our breeding programs, Hendrix Genetics does not currently use any form of gene modification. We, however, continue to closely monitor the rapid developments in gene editing and invest in research in this new technology to evaluate its potential application. Gene editing will help us to get a better understanding of genes and mutations in genes that contribute to genetic variation in traits. That knowledge can be used to improve genomic selection schemes provided that the desired variants are present in the population. When the desired variant is not present, genetic improvement via gene editing is an innovative solution.

Investment in research into gene editing does not imply that Hendrix Genetics will necessarily use this technology in the future. Before using a new technology, we need to understand the full impact of it on animals, animal products and humans. We must be convinced of the added value of gene editing before entering any discussion on commercial application. Such discussion will not only cover technical issues but more important ethical and regulatory issues. Now, Hendrix Genetics sees several critical challenges ahead for gene editing that must be resolved before commercial application can even be considered.

Even with satisfactory results from research, Hendrix Genetics would only ever consider gene editing for applications when it clearly outperforms any alternatives. The most likely application of gene editing appears to be to improve the health and welfare of farm animals (including fish). It is very unlikely that we will use gene editing for realizing higher production efficiency directly. We are, for example, involved in research on the opportunity to use gene editing to stop surgical castration of male pigs.

POULTRY BREEDING FOR AFRICAN SMALLHOLDER FARMERS

There is a wide variation in climate, production circumstances and consumer preferences around the world. This implies that when it comes to animal breeding, one size does not fit all. As an international breeding organisation, we need to have a product portfolio to meet that diversity. This can be illustrated when looking at smallholder farmers in Africa. To also meet their needs, we not only breed birds that are specialized in egg production but also dual-purpose birds, intended to produce both eggs and meat.

Poultry constitutes an important economic activity for the rural poor in many African countries. Several researchers have shown that the performance of smallholder poultry production can be greatly improved by using improved genetics. The local indigenous breeds are inefficient and unproductive compared to other alternative breed options, such as Sasso and Kuroiler. In many instances the smallholder farmers in rural areas do not have access to improved genetics and are forced to use birds that have low levels of productivity and high mortality rates. The access to an improved low-input and dual-purpose chicken to supplement the local indigenous breeds has the potential to transform the rural poultry enterprise.

This situation can be changed as demonstrated by the African Poultry Multiplication Initiative (APMI) led by the World Poultry Foundation (WPF), with investments in Uganda, Ethiopia, Tanzania, and Nigeria as well as other poultry initiatives in Burkina Faso. The APMI model operates through capable local private companies to establish a parent stock and hatchery operation for the supply of improved genetics of low-input, dual purpose chicken breeds to farmers in their communities. These initiatives are dependent on access to poultry parent stock for the improved breeds. We have partnered with WPF to ensure reliable access to improved parent stock genetics. The supply of parent stock is frequently disrupted by outbreaks of diseases such as avian influenza. An outbreak of avian influenza in the source country leads to a ban on export of parent stock. A long-term sustainable solution to mitigate this risk is duplication of the germplasm at multiple locations.

Although breeds such as Kuroiler and Sasso perform better than most local ecotypes, the productivity and feed utilization efficiency of these breeds is far lower than current commercial breeds. Results from ILRI's African Chicken Genetic Gain project shows that there is a wide variability in the performance of Kuroiler and Sasso in different agro ecologies. We have, therefore, implemented a genetic improvement program to further improve the productivity, adaptability, and resilience of the lines that are used to produce the dual-purpose breed. The genetic gain of the lines may be further accelerated by the application of genomics selection. However, implementation of this technology for the benefit of smallholder farmers in Africa has failed due a combination of two factors. First, the lack of support for such genetic improvement schemes to develop proper infrastructure (such as performance recording and genetic evaluation schemes). Second, the lack of a system to sustainably multiply and distribute the improved genetic material to the smallholders. We aim to overcome these factors due to our experience and knowledge and more importantly our access to a larger international market. The ability to sell genetic material in multiple countries is crucial for offsetting the cost of a breeding program to improve the dual-purpose chicken. With these improved breeds, smallholder farmers in Africa are not only able to increase their income but also to contribute to feeding the growing population with nutritious protein.

COLLABORATION

In order to find sustainable solutions for the global food challenge, we are continuously exploring innovations in the domain of measuring health, welfare and productivity of animals. These innovations need to be based not only on a solid understanding of the underlying biology but also on an overall view on the issue at stake. Developing a solid understanding is an important but not the only driver to be involved in research collaboration with knowledge institutes. Equally important drivers for participation in a research project are creating awareness in the scientific community for the issues involved in improving sustainability and training a new generation of researchers. Solving sustainability issues often requires collaboration in multidisciplinary teams. Industry participation in research projects is expected to speed-up innovations and contribute to training of new talents that are focussed on generating solutions. Collaboration is therefore crucial for realizing sustainable solutions for the global food challenge.

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