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ANIMAL BREEDING IS PART OF THE SOLUTION TO ENVIRONMENT, CLIMATE, AND ANIMAL-WELFARE CHALLENGES FACING ANIMAL PRODUCTION

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SUMMARY

We argue that animal breeding is part of the solution to a major challenge facing animal production: community concerns for the environment, climate change, and animal welfare. Animal production will increasingly be expected to use fewer resources, reduce its impact on the environment and climate, and improve animal welfare. Animal breeders can provide animals with genetics that make them productive in future, reshaped, production systems by defining breeding objectives with traits that benefit the environment, climate, and animal welfare. Breeders are well-equipped to make gains in these breeding objectives because they can predict breeding values accurately. These accuracies will only increase as new genetic technologies become available, leading to even faster gains. However, faster gains also call for caution because they increase the risk of unintended side effects. To manage this increased risk, breeders should consider three safeguards: control of inbreeding, reliable selection criteria, and monitoring and surveillance of animals. Another safeguard is maintaining many populations of commercial breeds. It's an exciting time for animal production, and breeders must be there providing the genetics.

ANIMAL BREEDING IS PART OF THE SOLUTION

Animal breeders use selection to improve desirable traits in animal populations. The underlying principle is to rank animals for these traits and choose the best to be parents of the next generation while controlling rates of inbreeding at acceptable levels. This principle will not change in future. What is likely to change is the direction of this selection – the composition of traits in our breeding objectives – as animal production wrestles with community concerns for the environment, climate change, and animal welfare. We have little doubt that animal production has a future. Animals provide humans with high-quality protein, essential nutrients, and non-synthetic products; they convert biomass that is unsuitable for human consumption into food, manure, and ecosystem services; they utilise land that cannot be used to produce other types of food; and they are deeply embedded into the economies and cultures of societies around the world. However, like most other businesses, these benefits come at a cost. Animal production uses land, water, and energy, it degrades and pollutes terrestrial and aquatic ecosystems, it encourages deforestation, it emits greenhouse gasses, and it rears animals in captivity. Assuming communities are well fed and have their basic needs met, animal production will increasingly be expected to use fewer resources, reduce its impact on the environment and climate, and improve animal welfare. This is where animal breeding must play a key role by providing animals that are genetically suited to production systems of the future. Therefore, we argue that animal breeding is part of the solution to the challenges facing future animal production. Other solutions, which we do not address here, are to increase plant consumption, reduce animal consumption in wealthy countries, replace conventional meat with cultivated meat, and reduce food wastage. We see our paper as a summary of opportunity and a call to action. Our primary focus is on large, centralised breeding schemes as we believe that these schemes will provide most of the world's genetics in future.

ANIMAL PRODUCTION IS CHANGING

Modern animal production requires a "licence to produce". Animal products need to be produced and supplied in a way that eases the community's concern for the environment, climate change, and animal welfare. Governments, particularly in wealthy countries, are reacting to these concerns. They are introducing change in the form of legislation, incentives, and penalties to balance the economic benefits of animal production with its impact on the environment, climate, and animal welfare. For example, New Zealand's government will charge farmers for the greenhouse gases emitted by their livestock. The Dutch and Belgian Governments will halve nitrogen emissions by reducing livestock numbers. The German Government has already introduced strict requirements for animal welfare with a short phase-in period and did so without consulting any animal sectors. The European Commission will phase out cage production of farmed animals. In response to these changes, we must expand our definition of productivity to include economic incentives and penalties associated with the environment, climate, and animal welfare. They will almost certainly lead to new production systems with revamped management strategies and husbandry practices as producers cope with the new legislation, pursue the incentives, and avoid the penalties. The impact of these changes could be substantial. For example, producers that use cattle feedlots will need to improve animal welfare and reduce their impact on the environment and climate. Intensive pig, chicken, and fish enterprises may have reduced their impacts on the environment and climate, but they still cause animal-welfare concerns. Organic pig and chicken productions have improved animal welfare, but still have an impact on the environment and climate. We will probably also see new and efficient species introduced into production systems. A prime example is the growing interest in insects and microorganisms reared on waste products to generate food and animal feed. No matter what the production system, they all have one thing in common: they all require animals – including insects and microorganisms – with genetics that make them productive. So, animal production is changing because our definition of productivity is changing, requiring animals with genetics that make them productive in future, reshaped, production systems.

BREEDING OBJECTIVES FOR ENVIRONMENT, CLIMATE, ANIMAL WELFARE

Animal breeders can provide animals genetically capable of being productive in future production systems by defining new breeding objectives. Breeders define breeding objectives by identifying the traits they want to improve and deriving economic values that allocate an appropriate amount of selection pressure to each of these traits. New breeding objectives will almost certainly include most, if not all, of the traits in current breeding objectives, including growth rate, feed efficiency, meat and milk yields, fleece weight, litter size, and survival. Not only do these traits increase economic returns, they also benefit the environment, climate, and animal welfare by increasing production efficiency. So, new breeding objectives will reflect current breeding objectives, but there are likely to be two striking differences. First, these breeding objectives will also include new traits directed towards benefiting the environment, climate, or animal welfare. Possible examples include reduced emissions of nitrogen, phosphorus, and methane, lower production odours, and tail biting. Second, the economic values allocated to each trait will change to shift some selection pressure towards traits associated with the environment, climate, and animal welfare. Deriving some of these economic values could be particularly challenging for traits, such as survival and conformation disorders, that infer a "licence to produce". Economic values for these traits can have "non-market" values that are much larger than any profit margin when the phenotypic means of the traits fall below levels that are acceptable to the community. Non-acceptable standards can trigger government legislation, consumer boycotts and, in extreme cases, shut whole industries down. The problem for breeders is that they will be compelled to foresee "non-market" values for traits when the level of community acceptance in future is fraught with uncertainty. Therefore, defining new breeding objectives with traits that benefit the environment, climate, and animal welfare is certain to be challenging, but it is critical that we tackle these challenges because breeding objectives are the only lever breeders have to increase productivity in future production systems.

ANIMAL BREEDERS NEED STRONG SIGNALS

Animal breeders who practice good business management are unlikely to be "first movers" because they need certainty before they change their breeding objectives. Breeders make selection decisions based on projected market conditions but there is a time lag before genetic gains made from these decisions are realised and disseminated to producers. If these projected conditions are incorrect, breeders risk wasting selection pressure on improving traits that are not profitable. Governments and the community can assist all vested stakeholders in animal production by providing breeders with strong and early market signals. These signals are long-term legislation, incentives, and penalties directed at producers. They would enable breeders to define with confidence breeding objectives that provide a clear direction for selection, avoid selection for traits that can be improved by non-genetic methods, resist selection for traits that are merely indicators of productivity, and hasten the time before animals with improved productivity are disseminated to producers. So, we recommend that governments and the community provide breeders with strong and early market signals directed at producers. This is in the best interests of all vested stakeholders.

MAKING FAST GENETIC GAINS SAFELY

Modern animal breeders are well-equipped to make gains in their breeding objectives because they are good at ranking animals. They predict breeding values accurately by fitting sophisticated genetic-statistical models to phenotypes, pedigree relationships, and genomic information. This accuracy will increase further in future as breeders develop better genetic-statistical models, improve phenotyping strategies, and acquire new genetic technologies, such as intermediate phenotypes, genetic engineering, gene editing, and gene networking. This is good news for animal production because it implies faster genetic gains. However, faster gains also call for caution because animal breeding is, and will remain in the foreseeable future, a "black box" technique. Breeders make genetic gains without understanding the full genetic and physiological consequences of selection. Some of these consequences can be unintended behavioural, physiological, metabolic, reproductive, and immunological side effects caused by genetic correlations between these effects and the traits in breeding objectives. Faster genetic gains merely increase the risk of these side effects. Clearly, we need improved safeguards to manage the increased risk of unintended side effects with faster genetic gains. We suggest three safeguards that should be considered by animal breeders to address this problem.

1. Control of inbreeding. Controlling inbreeding within populations at acceptable rates is a safeguard against unintended side effects because it maintains genetic variation, reduces inbreeding depression, decreases the spread of deleterious recessives, and reduces variability in the rate of genetic gain. Unfortunately, control of inbreeding in selective breeding schemes is struggling to keep pace with the fast genetic gains being realised by highly accurate predictions using genomic information. We see three key issues that need to be resolved before we can control inbreeding effectively in these schemes. First, there is no consensus on the most appropriate definition of inbreeding following the advent of genomic information. Do we control identity-by-descent (IBD), loss of heterozygosity, or genetic drift? Second, we have not learnt to control inbreeding with genomic information in selective breeding schemes. Breeding schemes that use pedigree information to control inbreeding realise more genetic gain than genomic information at the same rate of IBD. This leads us to reason that pedigree control is the method-of-choice for inbreeding control in selective breeding programs. Genomic control is unlikely to realise more genetic gain than pedigree control until we understand which regions of the genome harbour quantitative trait loci and we can manage genetic variation along the genome. A notable caveat is that pedigree control tends to underestimate rates of IBD when genomic information is used to predict breeding values. This implies that pedigree inbreeding should be controlled at rates lower than desired rates of IBD. Third, optimum-contribution selection (OCS) is the best method of selection because it maximises genetic gain for a given rate of inbreeding, but is not used in many breeding schemes because it can be difficult to implement in practice. With the promise of faster genetic gains, we urgently need to adapt OCS to conform to the practical aspects of animal breeding. Selection decisions made by OCS are not always optimal because reproductive biology and logistical constraints can be more complex than the input data we provide OCS software. There can be a mismatch between OCS decisions made centrally at discrete time points and the true optimum for any given day. So, there is clearly a lot of work to do before we have effective inbreeding control with fast genetic gains. Until then, we recommend pedigree control of inbreeding while correcting for the fact that pedigree underestimates rates of IBD.

2. Reliable selection criteria. Identifying reliable selection criteria for traits in the breeding objective provides a safeguard against unintended side effects by enabling breeders to allocate an appropriate amount of selection pressure to traits associated with the environment, climate, and animal welfare. The most reliable selection criteria are phenotypes that are easy to measure, express genetic variation, are genetically correlated with one or more traits in the breeding objective, and can be recorded for many selection candidates or their relatives. The challenge for breeders is that traits associated with the environment, climate, and animal welfare are often difficult to measure. Developing suitable and usable selection criteria for these traits must be a priority. Without them, we will forego potential gains in our breeding objectives by failing to allocate the correct amount of selection pressure to each trait. So, while it is key to include traits associated with the environment, climate, and animal welfare in breeding objectives, it is also important that we identify selection criteria that enable us to improve these traits by selection.

3. Monitoring, surveillance, and communication. Close monitoring and surveillance of animals is an important safeguard against unintended side effects by uncovering some of these effects before they spread through breeding populations. No monitoring or surveillance will uncover all unintended side effects, given that selection acts at the molecular level. However, we can increase the probability of uncovering them by routine evaluation using human assessment and surveillance technologies carried out by stakeholders with a vested interest in animal welfare. These stakeholders can be active at all levels of production and include animal breeders, producers, veterinarians, abattoir operators, retailers, and scientists. The side effects that they uncover are relayed back to the animal breeder who can then begin to rectify the effects. So, animal breeders can manage the increased risk of unintended side effects with faster genetic gains by communicating closely with vested stakeholders who routinely evaluate the animals generated by breeding.

MANY BREEDING POPULATIONS FOR BREED SECURITY

Like the safeguards against unintended side effects within animal populations, maintaining many populations of each commercial breed can provide a safeguard against production changes and market uncertainty. Maintaining many populations conserves genetic variation. It increases the probability that some populations will cope with change better than others. It also enables producers to choose animals from populations best suited to their production systems. However, maintaining many breeding populations is at odds with the business strategies and commercial goals of breeding companies for three reasons. First, like other businesses, breeding companies compete, go bankrupt, merge, exclude new entrants, and seek to monopolise global markets. For example, the world's genetics for broiler chickens is now supplied by only three companies and most of the pig genetics is supplied by just six companies. Second, breeding populations that do not make a return on investment are discontinued, and discontinued populations are seldom replaced. Third, breeding companies with the same commercial breed define similar breeding objectives for their populations so that these populations tend to converge genetically. The result is few breeding companies maintaining few breeding populations and these populations tend to resemble each other. This makes many commercial breeds vulnerable to market fluctuations and they risk being replaced by other breeds, species, and even alternative food sources. We need to balance the economic drive to concentrate breeding populations with the need to maintain populations. This balance could be achieved through government intervention to resist global monopolisation of genetic resources. So, we have a choice. We can leave breed security to the mercy of breeding companies and economic forces, or we can intervene to resist global monopolisation. We advocate for intervention.

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