Better breeding decisions through the use of advanced technology

Ask ADAM. That is what the Danish Agriculture & Food Council does before it proposes any changes to its pig breeding programme.

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How much extra genetic gain can we realise over the next five, 10, or even 20 years, if we genotype all pigs in the nucleus herds?

What if we modify the breeding goal? Can we realise more genetic gain for feed efficiency by measuring the total amount of feed eaten by groups of pigs? Do we realise more genetic gain for piglet survival, if we genotype piglets that die?

ADAM can help answer these and a multitude of other questions. Like a crystal ball, it can predict the outcome of proposed changes to animal breeding schemes. The Breeding & Genetics department at Danish Agriculture & Food Council uses ADAM to help make better breeding decisions for DanBred's pig breeding scheme.

That means a more efficient breeding scheme with more genetic gain for pig producers and managers of breeding and multiplier herds.

ADAM simulates animal breeding schemes

ADAM is a computer program – developed by Aarhus University and Breeding & Genetics – that simulates animal breeding schemes. It simulates a population of animals and traces the genetic change in the population over time under a specific breeding scenario.

One of the benefits of ADAM is that it allows a plethora of breeding scenarios to be evaluated. It can cater for a wide range of genetic architectures, population structures, selection methods, mating designs, genotyping and phenotyping strategies, and management practices.

This implies that the number of breeding scenarios that can be tested and explored is endless. ADAM generates computer-simulated pigs, each with their own unique DNA. The simulated pigs are selected and mated. Sows produce litters. Pigs survive or die. They can be reared at breeding and multiplier herds, transferred to a test station(s), performance tested, genotyped, and culled. It is the closest we can come to the real world. The main difference is that pigs living in the virtual world of ADAM do not end up as real bacon.

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Example

Genomic selection realises more genetic gain than traditional pedigree-based breeding. However, Breeding & Genetics would like to know how much extra gain they could expect by implementing genomic selection in the DanBred Duroc breed.

This implies that we need to predict the rate of genetic gain realised by two scenarios:

- A breeding system with selection based on genomic-based breeding values, hereafter referred to as 'genomic'.
- A breeding system with traditional pedigree-based breeding values ('pedigree').

Each scenario is initiated by generating a breeding population with 2,000 sows and 100 boars. Each animal in the population has its own unique genotype: a 30-M genome made up of 18 pairs of autosomal chromosomes with 8,000 quantitative trait loci (QTL) and 50,000 marker loci. The QTL and markers are randomly distributed across the genome and in linkage disequilibrium.

The number of chromosomes and amount of linkage disequilibrium between alleles at the markers are simulated to resemble those in Duroc.

In the DanBred breeding goal for Duroc, the 8,000 QTL code for: litter size, survival, growth rate, feed efficiency, meat percentage, and conformation score. The true genetic potential of each animal for each trait is determined by the two alleles it has inherited at each QTL. The animal's phenotype for each trait is then the sum of its true genetic potential and the influence of the environment.

We run the two scenarios – genomic and pedigree – for 10 generations. In each generation, we select the best 2,000 sows and 100 boars as parents to the next generation. The best sows and boars are selected based on genomic-based breeding values estimated using the 50,000 marker loci in the genomic scenario. In the pedigree scenario, the best sows and boars were selected based on pedigree-based breeding values.

Each sow produces a litter of pigs. The size of her litter is determined by her phenotype for litter size. The genotype that each pig inherits from its parents is determined by the laws of Mendelian inheritance. The pigs survive or die.

A certain percentage of boars are transferred to a test station to be performance tested for traits, such as feed efficiency. But all pigs are also genotyped, and performance tested for growth rate, feed efficiency, meat percentage, and conformation score.

When the two scenarios have been run for 10 generations, we calculate the rate of genetic gain realised over the 10 generations in the genomic and pedigree scenarios.

We repeat each scenario 100 times and obtain the average genetic gain across the 100 replicates. The difference between the averages for the genomic and pedigree scenarios provides us with a reliable estimate of how much extra genetic gain we can expect by implementing genomic selection in the Duroc breed.

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Breeding & Genetics are not the only ones using ADAM. ADAM has been used by university scientists to test genetic hypotheses and develop new breeding methods. It has also been used by breeding companies to evaluate breeding schemes for pigs, dairy cattle, beef cattle, dogs, mink, and rainbow trout.

ADAM works

Simulations of animal-breeding schemes carried out in ADAM work for two reasons.

First, they are based on the laws of Mendelian inheritance.

These laws are over 100 years old and have withstood the test of time, despite numerous expert attempts to find flaws.

Second, all the input parameters used in the simulations – including trait means, heritabilities, genetic and phenotypic correlations – are derived from breeding populations. These two reasons make ADAM an accurate tool for simulating an animal breeding scheme.

Benefits of ADAM

There are three major benefits for using ADAM to simulate a breeding scheme.

● **First:** ADAM can simulate complex breeding schemes with interactions between multiple factors. This makes it an ideal tool to predict the outcome of proposed changes to the breeding scheme and to understand the mechanisms underlying these changes.

● **Second:** ADAM and other computer-simulation tools are the only practical methods to assess breeding decisions. We can not carry out 'real-life' selection experiments with our pigs that run for 5-10 years, every time we want to make changes to the breeding scheme or test a scenario. The number of pigs, time, and costs involved makes that impractical. So, computer-simulation is really the only option.

● **Third:** ADAM allows us to be creative. We can ask any number of 'what if?'-questions and test scenarios that seem far-fetched and out-of-reach with today's technology. What if we genotyped all of our dead piglets? What if we could genotype pigs with a phone app? What if we use CRISPR technology? What if we could performance test all selection candidates for feed efficiency. It is creativity that will bring about the most significant advances for a breeding scheme.

ADAM requires thought

Running simulations in ADAM takes time and planning. It takes more than just pressing 'return' on the computer to run an ADAM simulation. The predictions that come out of the program can only be as good as the information we put into it.

We still need to understand the genetic mechanisms underlying different traits, the structure of the pig population, and the selection strategy – to mention a few of the many input parameters needed.

We also need to design experiments carefully and apply the same scientific principles, as if we were carrying out an experiment in real life. There is no way around that. ■