THEMATIC ARTICLE

Balancing gain and resilience!

Breeding cattle for heat resilience, fertility, health and long-term diversity

EXECUTIVE SUMMARY

RUMIGEN used quantitative genetics to turn large-scale farm, pedigree, genomic and weather data into practical knowledge for climate-resilient and diversity-aware breeding. The project defined heat-tolerance traits, studied trade-offs between production, fertility and udder health, assessed effects of genomic selection on local-breed diversity, and developed methods to manage genetic gain without losing diversity, rare alleles or future breeding options.

THE ISSUE

Climate change is already changing the conditions under which dairy cattle are expected to perform. Heat stress can reduce milk production, affect fertility, increase pressure on udder health and compromise welfare. The difficult part is that animals do not respond to heat stress in one simple way. A cow that performs well under normal conditions may not be the most resilient under high temperature-humidity conditions.

This creates a breeding dilemma. Selection for high production has brought major gains, but future breeding programmes must also account for resilience, fertility, health and environmental adaptation. If these trade-offs are ignored, breeding may continue to improve short-term output while increasing vulnerability to heat, disease pressure or reproductive decline.

There is a second risk: genetic progress can become too narrow. Genomic selection is powerful, but if it is not managed carefully, it can reduce genetic diversity, increase inbreeding, lose rare favourable alleles and limit future adaptation. This is especially important for local and smaller cattle breeds, where population size and diversity management are already more fragile.

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RUMIGEN contribution to solutions

RUMIGEN turned routine data into climate-relevant breeding knowledge. The project combined milk recording, fertility data, somatic cell score, pedigree and genomic information with meteorological data to measure how cattle performance changes under different heat conditions.

A major contribution was the definition of heat-tolerance traits in practical breeding terms. RUMIGEN showed that heat tolerance can be described in two useful ways: the level of performance an animal maintains under heat stress, and the slope of decline when heat stress increases. This distinction matters. A cow is not resilient only because she produces more; she is resilient if her performance, fertility and health decline less when conditions become difficult.

The project also showed that heat stress affects different traits differently. Milk yield, milk components, fertility and udder health do not all respond in the same way. In some analyses, heat stress was linked with greater udder health pressure, while fertility studies showed that heat load can change genetic variation and sire rankings. This means that breeding for heat resilience cannot rely on a single production indicator.

RUMIGEN's work on production-fertility trade-offs is particularly important. The results show that breeding for thermotolerance should not focus only on milk production losses. Fertility under heat stress must also be considered, because animals that maintain production are not automatically the animals that maintain reproductive performance.

The project also examined whether heat stress experienced by pregnant cows affects the later performance of their daughters. Under the French climate conditions studied, these effects were generally limited, especially for fertility and udder health. This should be read carefully: it does not mean in utero heat stress can be ignored everywhere. It means that stronger effects may still appear under warmer or more extreme climate conditions.

On genetic diversity, RUMIGEN provided a more balanced message than the usual oversimplification. Genomic selection does not automatically damage diversity. Poorly managed selection does. In the local cattle breeds studied, large expected increases in inbreeding after genomic selection were not consistently observed. The key message is that the way breeding programmes are managed matters more than the technology alone.

RUMIGEN also developed and tested methods to better manage genetic gain, inbreeding depression, rare alleles, genetic load and structural genomic variation. This supports the principle of balanced breeding: improving animals for multiple traits while maintaining the genetic resources needed for future adaptation. This logic is well aligned with the Code EFABAR approach, where breeding goals should consider animal health, welfare, efficiency, environmental impact and genetic diversity together.

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Applications and potential impact

For breeding companies and genetic evaluation centres, RUMIGEN provides a stronger basis for developing heat-tolerance evaluations. It does not deliver one universal index that can simply be copied across all breeds and countries. What it provides is a scientific basis for deciding which traits to include, how to model them, and why production, fertility and health must be assessed together.

For breed societies, the near-term message is practical: keep strengthening traits such as fertility and udder health in breeding objectives, because these are already measurable, relevant to resilience, and important under heat stress. In the medium term, heat-tolerance traits can be integrated more directly once routine systems can reliably combine performance, pedigree, genomic and weather data.

For local and smaller breed programmes, the results support a smarter use of genomic tools. The right response is not to avoid genomic selection, but to use it with safeguards: monitor inbreeding, manage genetic drift, protect diversity and avoid losing useful rare variation.

For policymakers, the message is blunt: climate adaptation in livestock cannot rely only on farm management. Ventilation, shade, nutrition and housing matter, but breeding offers a permanent and cumulative route to adaptation. Data infrastructure and genetic evaluation capacity should therefore be treated as part of climate-resilience policy.

For farmers, the long-term value is better breeding decisions that deliver animals suited to real farm conditions: productive, fertile, healthy and more stable when environmental pressure increases.

Conclusions

RUMIGEN shows that future cattle breeding must move beyond production alone. The sector needs animals that can perform, reproduce and stay healthy under more variable environmental conditions, while preserving the genetic diversity needed for future challenges.

The strongest message is clear: heat resilience is measurable, but it is not simple. It depends on the trait, the breed, the environment and the breeding objective. RUMIGEN gives the sector the evidence and methods to handle that complexity more intelligently.

The next step is to translate this evidence into balanced breeding programmes that combine productivity with resilience, fertility, health, welfare and genetic diversity. In practice, this means designing breeding goals that do not optimise one trait in isolation, but support animals that are better adapted to future environmental conditions while maintaining long-term genetic progress and diversity.

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