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ROBUSTMILK – an EU-wide programme to improve the robustness of dairy cows and to make their milk healthier for humans

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Background

Dairy cattle have been selected primarily on production for over 20 years in many EU countries. This has been mostly as a result of importation of genetic material from North America followed by within-country selection policies specific to each country's local production systems. In the majority of countries, selection has traditionally favoured milk or protein yield whilst in a few countries the focus has been more balanced towards improved milk production without compromising health and fertility. Focussed selection for milk production has resulted in impressive improvements in milk production but has also resulted in dairy cows that lose large quantities of body energy reserves and are in varying degrees of negative energy balance (i.e. energy ingested is less than energy expended) for some parts of the lactation. Consequently, modern day dairy cows are considered less 'robust' than previously and this has serious implications for the health and fertility of the modern day dairy cow.

More recently, as a result of a general public interest in modern day milk production systems and their potential impact on the environment,

selection pressure in many (if not all) countries has shifted more towards non-production traits. These non-production traits are mostly those associated with cow health, but increasingly the associations between the products of dairy (and beef) cows and human health is of interest. If anything, this is going to intensify in the very near future, especially as retailers try to identify a competitive advantage in their product over that of competitors (e.g. low fat milk).

What is ROBUSTMILK?

ROBUSTMILK is a project that has been funded through the EU Framework 7 Programme to join together six world-leading research organisations within EU that are actively working in dairy cattle breeding and have strong links with the dairy industry. It is called **Innovative and Practical Breeding Tools for Improved Dairy Products from More Robust Dairy Cattle** abbreviated to ROBUSTMILK for ease of use (and speed!).

Who is involved?

There are six organisations involved in the project and all have a strong background in dairy cattle breeding.

They are all well respected in their own countries and each has a strong reputation for ensuring that research and innovation is disseminated quickly to industry. These organisations are:

1. Animal Science Group, Lelystad (Netherlands)
2. The Scottish Agricultural College (SAC Scotland)
3. Teagasc Moorepark (Ireland)
4. Gembloux Agricultural University (Belgium)
5. Swedish University of Agricultural Science (Sweden)
6. Wageningen University (Netherlands)

What will ROBUSTMILK do?

The objective of ROBUSTMILK is to develop new, useful and practical technologies to allow dairy farmers and the dairy industry to refocus their selection decisions to include additional traits such as milk quality and dairy cow robustness. It is of utmost importance that farmers can evaluate the consequences of selection for these novel and additional traits within their own milk production systems. Likewise, it is important that the inclusion of traits such as milk quality does not

compromise health, fertility, 'robustness', or in other words the profitability of the cow. We seek the win-win situation where dairy cow milk is healthy for humans and producing it is also healthy for the cow.

The overall objective of ROBUSTMILK will be achieved by having five integrated work packages each having their own objective:

1. The creation of a common database across country partners that includes unique and scarcely recorded measurements for traits underlying individual dairy cow robustness and milk quality. These traits include measures such as feed intake, regular body condition scoring and detailed health and fertility recordings. These databases are held at each of the research partners involved and the first thing to do is to create a framework that enables bringing that data together to make it useable by this and future projects.
2. To develop tools for easily and cheaply measuring dairy cow robustness (energy balance) and milk quality (lactoferrin and fatty acid composition). The tool pursued in ROBUSTMILK is mid-infrared spectrometry which is a methodology used to determine the fat, protein and lactose concentration of all milk samples from milk recorded herds internationally. Preliminary analyses indicated that equations could be developed using this methodology to predict milk fatty acid content; the objective of this task is to strengthen these calibration equations and evaluate whether they can also be used to predict dairy cow robustness.
3. A robust cow maintains good milk quality (e.g., low levels of somatic cell count, SCC) over a wide range of environments and also throughout her life. In this work package we will develop statistical tools to select for both types of robustness, with special emphasis on SCC. Increased SCC is an indicator of both compromised udder health and lowered milk quality – therefore decreasing SCC is an example of a win-win situation.
4. To develop genomic tools for selection for robustness and milk quality traits. The merged data from all of the partners will be accompanied by DNA from each of the animals so that new genomic technologies can be used to identify which DNA profiles are associated with 'good' milk and which with 'bad' milk and similarly can be used to differentiate between genes for high or low 'robustness'. Once identified, these markers can then be included in genetic evaluations thereby providing more power to individual farmers when making selection decisions. Such an objective cannot be achieved without strong and open collaboration among several research groups with access and willingness to share their individual cow records and DNA samples.
5. Integrate and disseminate knowledge on the consequences of selection practices on robustness and milk quality. ROBUSTMILK has the potential to enhance the competitiveness of European agriculture through the production of higher quality dairy products and more sustainable dairy production systems. ROBUSTMILK will contribute significantly towards the Knowledge Based Bio Economy objective of the EU, through a greater understanding of factors contributing to genetic variation and exploiting this variation in a sustainable manner in genetic improvement programmes. Research findings will be updated regularly at the ROBUSTMILK website (<http://www.robustmilk.eu/>)

What will be produced?

Primarily, knowledge will be generated but of course when this knowledge is applied, through the strong links between this research group and industry, the ultimate beneficiaries will be EU consumers.

For example, once we know the genetic profile of cows that have improved robustness and produce more healthy milk, then we can include this in selection programmes, farmers can choose better bulls to increase the profitability of their herd, and society will benefit from healthier food being produced by better cows. These cows will require less treatment for disease, will live longer and consequently dairy production from them will have less impact on the environment.

How will it benefit farmers and society?

Ultimately, when the research on milk quality is applied in a systematic manner within the food chain, healthier milk can be placed on supermarket shelves. At the same time we will know how to do this without compromising the health of the cow and so cows (and farmers) will benefit. Indeed, irrespective of the human health aspects of milk, this project will lead to cows that are more 'robust' which translates into cows that can produce large amounts of milk economically for the farmer, that can remain healthy in so doing and can live a long time without the need for veterinary intervention or drug usage. This benefits both farmers and society but above all, benefits cows and the environment, because herds with cows that live longer have an overall lower impact on the environment.

THE FIRST RESULTS

Measuring milk quality

The groups in Belgium, Edinburgh and Ireland have been very active in developing new methods of accurately and routinely predicting milk quality at little or no extra cost. The same machine in milk laboratories that determines fat and protein percentage in all milk samples (i.e. individual cows and bulk tank samples) also gives much more currently under-utilised information. Earlier work had already suggested that this information can be used to predict fatty acid composition in the milk. Fatty acid composition is of interest if we want to improve the

quality of the fat in the milk by altering the ratios of the different fatty acids. In ROBUSTMILK this methodology was further improved and validated in independent data from the UK, Ireland and The Netherlands. Accuracy of prediction for particularly the saturated fat content was extremely high and these equations are already being applied in Belgium. The infrastructure is present for applying this technology in other countries including the UK.

Measuring energy balance

The research work on using information gathered from milk samples to predict more difficult-to-measure traits such as milk fatty acid content have taken an important step further in ROBUSTMILK. ROBUSTMILK set out to answer the research question of whether or not we could identify patterns in the mid-infrared spectrum of milk that were associated with cow robustness or energy balance. The hypothesis was that this approach is already accurately used to predict milk fat and protein percentage and these are known to be associated with energy balance. Equations to predict energy balance from mid-infrared spectra in milk were developed using data from Scottish Agricultural College. The results are very promising. We can predict energy balance with an accuracy close to 75% which far supersedes any previous predictors suggested. This might not be good enough for treatment of individual cows, but for breeding purposes (where many samples are often combined for the whole lactation), this might become an important route for including energy balance in our breeding objectives. The prediction equations are currently being validated using Irish data.

Genetic evaluation

We have developed models that can estimate if the offspring from some sires are more variable than the offspring from other sires, and developed algorithms that are much faster than the currently used ones, thereby reducing the time to undertake routine genetic evaluations

for these types of traits. Furthermore, we have developed and studied some new traits that better take into account the changes in SCC over the lactation than does the current lactation average SCC, and found that heritabilities for these traits were in the range usually found for lactation average SCC (9–13%). We have also shown that we can predict the probability not only of moving from a healthy to a sick state, but also the probability of recovering from a sick state (a trait that has not been studied before) – both based on the dynamics of SCC. This has huge implications for how we genetically evaluate SCC and could result in greater genetic gain for udder health.

Database

We have put together an international database. At present a total of 4,473 animals have phenotypic data stored in the database, linking to 561,940 milk samples. Also we have genotyped these animals with 50,000 markers. The first genome wide association analyses milk yield, fat to protein ratio and somatic cell count. Regions of the genome associated with milk production were found on chromosomes 9, 10 and 14 and for fat to protein ratio on chromosomes 9, 17 and 27. Furthermore, regions on chromosome 20 were associated with somatic cell count and regions on chromosome 3, 10, 18 and 20 were associated with the variation in somatic cell count.

Feed efficiency

Although the ROBUSTMILK database might not be massive, most traits recorded on these animals are rare and unique especially the data on feed intake and feed efficiency is very timely. The first analysis of this dataset suggests that there are about 500 genes causing the variation in feed efficiency between animals, with one gene found that has a relatively strong effect. Interestingly, this gene also affects feed efficiency in poultry. In practice the individual genes found do not have a large enough effect to select on these individual genes, and the best solution to select for feed efficiency will be using genome wide

selection. From the first results, we predict that we need feed intake data on at least 5000 to 7500 cows to estimate breeding values with a high enough reliability for publication. This requires the collaboration of even more countries, and this is already underway.

Fertility

Analysis for fertility has been performed using milk progesterone. The shared datasets of four countries demonstrated that the physiological fertility traits had higher heritability than the traditional traits we use from insemination records. This also indicates that fertility is under greater genetic control than is sometimes anticipated. Performing a genome wide scan, interesting genes were found that might have played a role in the reduction of fertility in the last century. Interesting enough, one of these genes may affect both female and male fertility.

Genomic Selection

Genomic selection is now considered to be the optimal method of genetic evaluation in international dairy cattle populations. Genomic selection is based on utilizing the information on an animal's DNA profile as another source of information alongside other recorded traits such as milk yield, if available. The benefits of genomic selection are greater accuracy of identifying the genetic elite (and worse) animals at a younger age. However, progress in genomic selection is hampered by access to sufficiently large datasets to estimate the optimal DNA profile for a given trait. ROBUSTMILK has answered the potential of genomically selecting for difficult to measure traits (e.g., feed intake) but has also proven that by combining information from multiple traits the accuracy obtained using genomic selection can be increased thereby increasing genetic gain.

Take home messages

1. Cows can be improved by selection to be more efficient, more healthy and live longer.

2. Cows can be selected to produce milk that is more healthy for humans using easily available national data.
3. The objective of this project is to attempt to achieve both of the points above simultaneously in an effective and efficient manner.
4. The first results are very promising: 1) easy ways of measuring fatty acid composition and energy balance during routine milk samples, 2) genomic tools that will aid selection for unique

traits like feed intake and fertility, and 3) new measures for robustness and mastitis from existing data have been developed.

5. To exploit genomic selection collaboration is required – the more the merrier and countries or groups unwilling to co-operate will be left behind!

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