KTIF Final Report

Contents:

1. PROJECT TITLE/APPLICANT

1.1 Title: Fast Breeders
1.2 Overview of your company. Fastbreeders is an informal and highly collaborative grouping of 3 dairy farmers with very large farms in South West Scotland comprising a total of around 3,500 milking cows. Their production systems are characterised by very extensive grazing only and very strict annual calving interval.

Scotland's Rural College (SRUC) exists to deliver comprehensive skills, education and business support for Scotland's land-based industries, founded on world class and sector-leading research, education and consultancy. The integration of these three complementary 'knowledge exchange' services is of significant value to all with an interest in land-based activities – be they learners, businesses, communities or policy-makers. Competing demands and addressing new opportunities means the future for land-based industries will be extremely challenging. The next generation of business leaders and policy makers will need to be highly skilled and knowledgeable to navigate their way through a complex operating environment. To achieve this, we will support land-based communities and industries by drawing on our accomplished history of more than a century of success. Strong in our heritage, yet stronger still as SRUC, we will strive to lead the way in delivering economic, social and environmental benefits while providing a strong voice for our rural industries.

2. EXECUTIVE SUMMARY

2.1 Overview – Maximum 1 page.

The Fastbreeders project set out to evaluate and scope the deployment of an advanced reproduction technologies (ART) programme of accelerated female genetic improvement in 3 large block calving, predominantly grazing, herds in South West Scotland. At the start, the farmers involved had a very good idea of what they wanted to achieve but lacked the knowledge and experience to achieve it. They felt that conventional genetic improvement using high merit sires was too slow and imprecise for their specialised farming systems. We set out to engage with a separate specialist company with experience and a track record in in-vitro fertilisation (IVF) and embryo transfer (ET) to gather the information required to make a sensible economic appraisal of this technology applied in these farming circumstances. The company was open with their processes and costs and an independent economic analysis of the expected returns from accelerated female improvement showed that each embryo had to cost no more than £200 to make the programme viable. Current prices are about £400 per embryo. An Innovate UK grant application was made to develop protocols of deployment at scale that would allow prices to approximate the £200 needed to make it viable. This includes the on-farm animal handling to streamline the process and allow large scale IVF and ET to take place. This is all against a backdrop of maintaining the farm key performance indicator of calving and inseminating all cows within a very strict 6 weeks window.

It was recognised early in the project that the objectives could only be met with accurate sire recording within the herds. The process of identifying embryo donors required construction of an accurate pedigree. This was achieved by undertaking parentage discovery using the genotyped cows in the herds to assign daughter sire pairs using the list of sires that had been used in the herds and that had been genotyped. A number of bulls was added by genotype exchange with Irish Cattle Breeders Federation and the Danish Herdbook allowing imported females to be aligned to their sires and calves carried by in-calf heifers to be sire identified.

The project created a prototype software tool for ranking animals in this specialised production environment. It was based on the Cows Own Worth index created in Ireland and adapted for use in UK. It was deployed as an Excel worksheet which allowed the farmers to identify cows for keeping and culling which (by default) creates a list of potential donors. However, given that young heifers should be genetically superior to older cows, it follows that heifer genetic merit needs to be calculated to allow them also to be considered as donors.

Once animals were identified as ‘keep’ then the programme Matesel from Brian Kinghorn was used with a list of top potential sires ranked on Spring Calving Index (SCI) and that had other attributes considered vital to the Fastbreeders group such as good fertility to produce a mating list that maximised improvement at manageable levels of inbreeding.

Collaboration discussions have successfully taken place with an IVF company (Vytelle) and an Innovate UK application made to fund a programme to deploy IVF and ET in the 3 herds to produce 4000 embryos from the top 25% animals to replace the bottom 75%. Unfortunately, this application was unsuccessful but Vytelle have established a new lab in Dumfries to begin offering services to UK farmers. All involved are still pursuing funding opportunities to continue this line of very important work.

3. PROJECT DESCRIPTION

The key problem that this project will address is the inherently slow rate of genetic improvement in dairy cattle on the female side.

Position – a group of three farmers is seeking to take an innovative and collaborative approach to improving output of their dairy herds through genetic selection and advanced reproductive techniques. The process of genetic improvement in dairy cattle is undertaken on the basis of selecting the most highly rated bulls to cross with the most productive cows in any given herd. Bull selection by the farmer is influenced by the traits that are deemed to be the most desirable (profitable) for a particular management system and location. Thereafter the most promising heifer calves are selected to replace cows already in the herd. Depending on the culling level in the herd and the availability of heifer replacements, selection intensity (voluntary culling of low performing cows) on the cow side can be low.

The three farmers concerned all manage low input, spring and very tight block calving herds. In a spring calving herd, it is critical to maintain a tight calving pattern so it is typical to first artificially inseminate (AI) the cows using specially selected bulls and then to sweep up the remaining cows which have not conceived with a live beef bull. Typical rates of successful AI to conception run at 65%. It is the female calves of the inseminated cows (around half of the 65%) which are used to produce replacement heifers. Due to calf mortality and morbidity this effectively means most of the female calves are used as replacements and the opportunity for genetic selection of females is low.

Problem – there are a number of opportunities to improve the position highlighted. Firstly, it takes a long time. A cow inseminated in May 2018 would produce a calf in 2019 which itself would start producing in 2021. It would not be till the end of the second lactation in 2023 (5 years from birth) that its production potential could be fully assessed. Secondly it is wasteful. Only half of the calves conceived using conventional AI will result in the birth of a female. Thirdly the breeding accuracy of selecting bulls and matching them to females based on parentage information is around 35%. Finally, there is a potential flaw in this system as it is those cows who conceive through AI that provide the basis of the replacements. These animals are the most fertile but may not be the most productive, i.e. those that that produce the most milk solids. This combination of factors only allows dairy herds to improve over a long timeframe. Given the current uncertainty in dairy markets driven by volatility and Brexit this is a significant risk for the farmers since they maintain a large herd of cows where the worst are significantly worse than the best.

Possibilities – new technology is now being developed which will allow dairy farmers to increase the rate and accuracy of genetic gain and reduce waste. This can be achieved using three linked procedures. The first is to undertake a detailed analysis of existing production data to rank the cows in the participating herds. The second is to genomically test the livestock and match the genomic information against the production data to develop a SNP key. This can be used to detect genetic patterns that identify the potential performance of youngstock before they start production. It also allows the level of breeding accuracy to increase to around 55% and enables the capacity to reduce the generation interval. The third procedure is to use advanced artificial breeding technologies to produce higher numbers of female embryos from the highest merit cows to implant into recipient cows to produce many more genetically superior replacements than would be possible using traditional techniques. This allows a greater focus on genetically superior animals and a reduction on the wasteful process of producing male and inferior female calves. The process is highly innovative and although rapid genetic gains such as those proposed here have been achieved for milk production in goats, they have not been attempted in crossbred dairy cattle.

Proposal – the farmers involved in this project use a common method of milk production based on a grass-based system where cows are calved in spring and grazed outside thereafter. The longer-term proposal is to use a collaborative approach amongst these producers to obtain rapid genetic gain whereby the bottom 75% of the milking herd will be replaced by the young animals with the genetic potential of the top 25% over a three year time frame. This will be achieved using new reproductive technologies described in the paragraphs above and will enable the project participants to achieve much higher levels of profitability and to reduce greenhouse gas emissions per unit product. The overall project will be implemented in two stages. **The first stage, and the subject of this project, will investigate and determine the best method of applying the innovative breeding disciplines and technologies to ensure they deliver reproducible outcomes. It will deliver a plan to enable the transfer of existing technologies onto farm and how they can be managed.** It will also provide guidance on the appropriate strategies to adopt taking account of issues encompassing; finance, ethics, legal and environment. The second stage will be shaped by stage one and will fund the deployment of the artificial breeding technologies. Stage two will be funded by the farmers involved and through an application to Innovate UK.

4. FINANCE

4.1 Sum awarded: £99,788.92
4.2 Detail of spend: The subcontract of £11,000 was paid to SAOS for project management, interface with farmers, organising farm events, paperwork associated with grant. Time was allocated to Professor Mike Coffey and some work subcontracted to Connor Brown.
4.3 Note any underspend and explain why: No underspend was incurred.

5. PROJECT AIMS/OBJECTIVES

The aim of the project was to secure and improve the viability of the participating farmers using data analysis, genomics and breeding technologies to determine the feasibility to replace the bottom 75% of the cows in the three participating herds with offspring from the top 25% as quickly as possible.

The project had 3 main work packages.

1. Feasibility and identification of key risks.
   a. An early key risk was highlighted as being the inability to correctly identify superior animals from which to extract oocytes for IVF work. This could lead to sub optimal progress at best and dis-improvement at worst (if poor merit animals were erroneously identified as being high merit). This was in part related to the fact that milk recording in the three herds are at less frequent intervals than in those herds used in genetic evaluations. None of the herds qualified for UK EBV calculation due to the irregular milk recording frequency being lower than the minimum required by the ICAR standards applied by Edinburgh Genetic Evaluation Services (EGENES) and so all assessment of cow value as a breeder of replacements was based on phenotypic records.

      The biggest risk was that the price of IVF and ET to produce a sufficient number of embryos to raise the average herd genetic merit of the herds was not cost effective. This turned out to be the case under the current economic conditions. This was also found to be the case in most countries operating this type of scheme but in discussion with one Breeding company (Vytelle) it became evident that the process was undertaken in South America on beef farms quite routinely because scale and local operating costs made it feasible in beef cattle there.

      The technology for aspirating oocytes from cow's ovaries was found to be well developed but a third main risk (which effectively rendered the technique unusable) was the fact that oocyte yield was very variable between animals and the ability of the resulting embryo to create and maintain a pregnancy was not predictable. The project team then engaged with a breeding company to ascertain if a joint venture could be established that would allow for the development of protocols that would address the risk associated with variability in oocyte yield and thereby costs per embryo. These discussions are ongoing and led to an Innovate UK application to develop these protocols (subsequently rejected).

   b. Defining success. The project success was widespread in that the farmers gained an understanding of the process of IVF, ET genomic evaluations and cow selection and its prerequisites. The Fastbreeders Team have acquired a great deal of knowledge and perspective for the application of ART in their herds, especially with regards its value and the risks involved in obtaining that value. They have maintained interest and enthusiasm for knowledge surrounding the techniques and have continued to meet (virtually) after the project had officially finished.

Whilst the farmers would argue they are no wealthier now than when the project started (characteristically), they are intellectually richer and have engaged in forming a joint venture with a major international breeding company. All the Team now have orders of magnitude more knowledge, both about the technique its-self, but more importantly in the way that it can be successfully deployed in farming systems like their own. An important outcome is that they recognise the value of data generated from their own cows as a tool for better decision making.

An important part of the process identified by the farmers at the beginning of the project was to enable them to rank cows in their own herds on a ranking that reflects profitability in their specific farming circumstances. They were interested in the tool produced by the Irish Cattle Breeding Federation (ICBF) called Cows Own Worth (COW). This project created a version of that tool, adapted to incorporate Fastbreeders information. It was successfully deployed on all farms to identify animals for culling and retaining. This was a 100% success. Following that exercise the farmers are all now completely committed to widen record keeping in their herds such that their combined and expanded dataset can be a very valuable asset in the future. This is particularly true of data emanating from the process of IVF and ET since little data exists at the scale needed to understand the genetic basis of success of failure in this approach. Project applications continue to be developed to deploy this technology on their farms and exploit the data generated from it.

2. Economics of ART

Work package two, part a) modelled the economics of producing embryos from differing proportions of the top animals in the herd. Abacus Bio was subcontracted to provide that analysis since they are specialists in this type of analysis. Their report was accompanied by an Excel spreadsheet that allowed us to explore different scenarios for improvement. It was found that a maximum of £200 could be paid per embryo to make the gain worth implementing. It was also noted that as genetic gain increased, the potential for further gain became lower and so the cost of embryos had to decrease accordingly. At this point however, the selection intensity could be increased (more embryos from fewer elite cows) to keep improvement rates high enough to warrant continued expenditure. This can only continue until inbreeding becomes a problem and reinforces the use of a mate allocation programme such as Matesel that maximises improvement within a population at managed levels of inbreeding.

Work package two, part b) examined the various reproductive techniques available such as IVF, ET and very quickly concluded that the only one really worth considering in this context was ovum pick up (OPU) from genetically elite animals as young as is practically possible. This is because the herds cannot risk any intervention in milking animals that would increase the underlying risk of them not getting pregnant in the very tight 6 week mating window required to maintain maximum annual yields. Any extension to the mating window results in cows being dried off whilst still milking and thereby having a short lactation. The only technique considered worthy of consideration was felt to be OPU on high merit maiden heifers at around 9 months of age and freezing the subsequent embryos ready for implantation the following spring mating season. The limitation of this technique (as far as these farmers were concerned at the time) is that the identification of animals to act as donors of genetically elite oocytes required those animals to be genotyped and a genotype SNP key for crossbred cattle available from which to provide genomic predictions. Likewise, it could really only be applied through maiden heifers because of the potential negative impact on milking cows during the mating period. Some very high value milking cows may not be considered as donors because of the high risk of losing them from the milking herd.

3. Logistics for deployment

Work package 3 part a) identified those animals to act as donors. The question of ranking animals to enable the identification of the 'best' to act as donors required the construction of a customised herd index framework. This process was relatively simple to operate because starting weights for traits were based on the Spring Calving Index (SCI) used by AHDB Dairy to rank animals. A preliminary spreadsheet was constructed containing all the animals in each herd with all the relevant EBVs for each trait and a simple weighted summation of all traits created the Fastbreeders Herd Index (FHI) which included other important herd traits such as Johnes test result. After agreement that the FHI ranks animals in an order that reflects the farmers view of profitability in their dairy herd, animals could then be ranked and different cow donor data sets created. The Cows Own Worth index created by ICBF was adapted to suit the Fastbreeders requirements and a ranking tool created that helped the farmers list cows in order within their own farms and that aligned with their daily experience of those cows i.e. the tool ranked cows in broadly the same order that the farmers would.

Work package 3 part b) identified suitable sires. Sires were selected by the farm from the top list of Holstein (or Jersey) bulls ranked on SCI. These sires were then added to the Matesel programme along with the cows chosen for breeding and a mating allocation list produced. This also could only be undertaken after the pedigree had been correctly formed using existing records and genotypes because the programme maximises genetic improvement whilst restricting inbreeding and this requires pedigree for optimal use. Again, for those animals whose pedigree could not be correctly ascertained the mate allocation was sub optimal but the list of chosen sires was of sufficient high merit that little would be lost.

c) Work package 3 part c) developd a plan to manage inbreeding. The software package MateSel (Kinghorn et al) was used to allocate cows to bulls for all 3 farms to breed replacement females. These mating plans were utilised in the 2020 spring mating season. The measure of success was a mating plan for the best cows and chosen sires.

6. PROJECT OUTCOMES

The project has very successfully achieved all its stated objectives and achieved some additional objectives not in the proposal as a result of leveraging over 3800 genotypes from another funding source (CIEL). This allowed all animals on the 3 farms plus a number of sires to be genotyped, their parentage to be verified, and sires discovered where missing, and a prototype SNP key produced which allowed the farmers to genomically assess their young animals based on their own reference population of cows. A number of sire genotypes were obtained by exchange from Irish Cattle Breeders Federation (ICBF) and the Danish Herdbook allowing their offspring to be correctly assigned to sires within the Fastbreeders herds. Furthermore, the ability to assess young animals on their genomic merit was identified as a prerequisite to undertaking the entire process i.e. this project could not have actually produced a list of animals to use as embryo donors without genomic testing. A number of cows on one farm were purchased as in-calf heifers but no information on the breeding of the unborn calves was available. The farm that purchased them approached the Danish company that sold them and successfully obtained the parentage genotypes for a number of putative sires which will allow parent assignment for those calves when born. This entailed EGENES developing new procedures for importing these parentage genotypes (which are a subset of SNPs from a conventional genotype) and then using them in parentage assignment.

One of the objectives of high priority for the farmers was to have a tool that would allow selection of females in the herd to act as donors of female replacements, those to mate to a beef bull and those to cull. This was achieved by developing a spreadsheet for use by the farmers. This tool was based on the Cows Own Worth tool developed and deployed by ICBF in Ireland. It was tested/validated in Ireland and shown to have been translated correctly. Data was then received from the milk recording organisations for the 3 herds and uploaded into the spreadsheet. Genetic indices were obtained from AHDB Dairy website using the farms levy number. The ranking of animals to cull was extensively discussed with the individual farmers and was shown to be a high match to their own expectations by doing the ranking by hand. As such it was deemed to be validated and useful in their herds and is now used routinely by all 3 farms.

7. LESSONS LEARNED

Issues/Challenges: Early on in the project it became clear there were a number of prerequisites for successful outcomes that were not in existence at the participating farms at the outset and that were difficult to ascertain from information obtained from breeding companies. For this to be successful in other farms too, the prerequisites need to be addressed. Prerequisites included:

1. Animals must be accurately identified and have known pedigree to allow for conventional breeding values to be calculated.
2. Herds must be officially milk recorded to a standard that allows national genetic indices to be calculated (at least 4 tests per year) and ICAR approved.
3. To select animals to act as donors for IVF, all animals must be genotyped. Heifers must be genotyped before 6 months of age.
4. The yield of pregnancies from each ovum pickup event must be high enough to be economically viable (affects cost of each pregnancy).

5. The technology for OPU and ET was commercially sensitive and still in its infancy and needed to be at a more advanced stage to make it economically viable for routine genetic improvement.
6. The value of increased milk output from genetically superior cows is high enough to warrant replacing a proportion of cows through IVF and ET. This is farm dependant because high merit animals cannot increase as fast as low merit animals and so take longer to pay back their ET costs. Economic modelling showed that a maximum price of £200 per embryo made the improvement achieved through this route viable.
7. When breeding an entire herd from a limited number of animals (OPU donors) these animals must be accurately identified as elite. This requires genotyping and genomic predictions using a crossbred SNP key. This is the only known collection of crossbred dairy cow genotypes that can be used to form a reference population.
8. To ensure correct sire assignment and pedigree construction, it would be useful in future to genotype animals at birth and use the genotype information to create BCMS registration. Unfortunately, the time taken to genotype is longer than the 30 day limit for registration and thereby currently precludes the use of that technology for routine parentage assignment.

The project attracted a lot of attention early on since it started in April 2019 and we had an open day/farm event in late June 2019. Over 40 farmers attended an event at Glenapp farm and heard about the objectives of the project by a presentation and discussion. A number of farmers enquired about becoming involved in the project.

A number of meetings (6) have taken place between FastBreeders and 3 separate breeding companies keen to become involved in the project some form. The discussion has ranged from a simple transaction (supplying IVF services for a cost) to collaboration and then to becoming partners in joint venture. These discussions are ongoing due to the uncertain nature of the yield of pregnancies from IVF and OPU and therefore cost of achieving rapid genetic improvement. The outcome will be a joint venture that will act as a commercial entity that can become involved in Innovate UK funded projects to take the process further. A breeding company was selected from the portfolio of ‘suitors’ and an application made to Innovate UK for £2m to undertake a pilot programme to produce 4000 embryos over 3 years. It was unsuccessful but has created a document that can be used to develop the proposals further for different funding streams.

Unfortunately at the very end of the project when most of the promotional activity and farmer dissemination events were to take place, the Covid 19 lockdowns prevented that.

8. COMMUNICATION & ENGAGEMENT

Fastbreeders have set up a Twitter account (@Fastbreeders) and have been selectively tweeting about the project. The domain names fastbreeders.uk, .com, .org have been secured for future use after the project.

An open day was held at Glennapp Estate farm with attendance of over 40 farmers. A second open day was planned for the end of the project but Covid 19 prevented that from occurring. It will be undertaken later in the year when travel restrictions have been lifted.

Rory Christie was invited to be on a panel at the British Cattle Breeders Club conference (January 26th 2021) to discuss ‘anti fragility’ in dairy cows emanating from his experience in the Fastbreeders project.

9. KEY FINDINGS & RECOMMENDATIONS

- Deploying advanced reproductive technologies (ART) is high risk and high reward and is only achievable by scale of operation. The Fastbreeders group is sufficiently large and is very collaborative and so could take this step with suitable grant funding to de-risk the venture to acceptable levels that the farms can service.
- ART is still in its infancy and some work is required on methodology to improve success rate to create a commercial environment that can be predictably rolled out to other farms. This is the domain of the companies supplying the service.
- In a grazing environment where individual animal yields are low, the maximum price that can reasonably be paid per embryo is £200. When the embryos are being donated by the farmers own cows there is no premium for high genetic merit donors and so the cost becomes that of the process.
- High quality on farm record keeping is an absolute necessity for these technologies to be successful since embryo donors have a high impact on future herd profitability.
- Whole herd genotyping is required to ensure that superior animals are who they say they are and are actually superior, especially for young heifers selected as donors.
- BCMS regulations need to change to allow for genotype generated parentage to be sent to BCMS for animals at birth. We recommend that an official receipt for sending off tissue for genotyping within 30 days of birth should allow a further 60 days for BCMS registration from genotyping results.
- Across breed genomics is very new and the dataset created by the project is the largest of its type in the UK and represents significant IP for the project partners.

10. CONCLUSION

The use of advanced reproductive techniques by sufficiently skilled and motivated dairy farmers at a commercially viable price offers the dairy industry a way of accelerating genetic improvement in cows for specific grazing environments such as those practiced in South West Scotland by the Fastbreeders group. That process can also be used by other

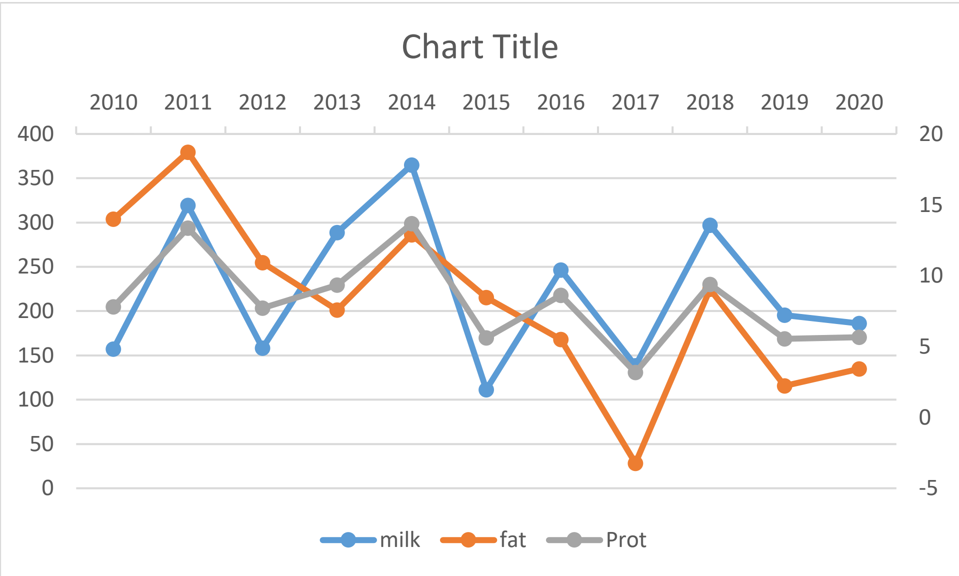
farmers once a list of prerequisites is met that requires some investment in genotyping and higher levels of on-farm record keeping.

The process of funding the engagement of specific groups of farmers with academics appears to have worked well on this occasion and has created a grouping that is motivated to continue and to seek further funding opportunities to exploit the techniques identified by the project. Continued funding to take a technology through to exploitation as an example case would be extremely worthwhile to create something for other farmers to consider.

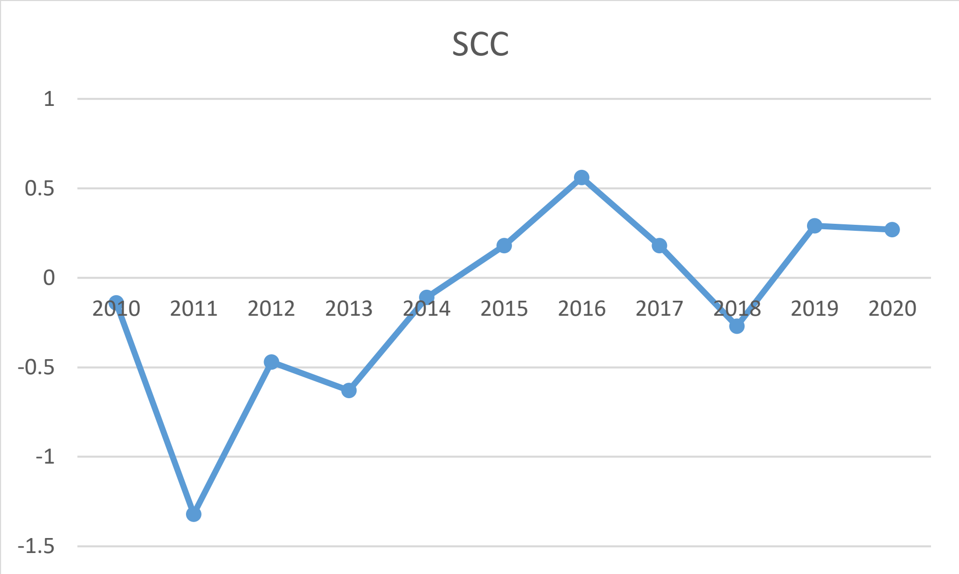
11. ANNEXES

Genetic trends based on genotyped animals.

Production trends are variable over years and reflect an inconsistent selection policy. There has been little overall genetic improvement over the combined three herds.



Somatic cell count (SCC) is a proxy measure for udder health and is measured routinely in milk samples taken at milk recording time. The trend in the UK has been down (favourable) but in Fastbreeders herds an unintended trend upwards has been observed. This is likely due to insufficient emphasis being placed on SCC in the selection criteria for bulls.



List of top 10 cows

an	anin	animal_id	milk	fat	Prot	fat_PC	prot_PC	SCC
F	4	583369609034	1835.999	76.6092	70.0691	0.041726	0.038164	-0.01041
F	4	583369509019	1534.947	39.1936	63.2318	0.025534	0.041195	-0.01852
F	1	583369309178	1490.291	21.4277	60.3414	0.014378	0.04049	0.00618
M	62	108237	1421.126	30.0111	51.5411	0.021118	0.036268	-0.01042
F	1	580456406209	1359.048	19.5554	50.4672	0.014389	0.037134	0.00173
F	1	583369109330	1318.163	54.2773	52.4207	0.041176	0.039768	0.01001
F	4	583369606885	1300.203	59.5982	40.1341	0.045838	0.030868	-0.00259
F	1	580456404970	1280.177	35.1193	46.1261	0.027433	0.036031	0.01387
F	1	101711403743	1271.951	17.6396	43.7879	0.013868	0.034426	0.00417

In discussion, the top cow in the list was identified as one of the best cows on the farm. Interestingly, the AI bull in position 4 was a Danish Jersey that came out very well when evaluated in a cross breed SNP key, demonstrating that the system was working well.