Future genetic trends for grass based dairying

A report for

NUFFIELD IRELAND

Farming Scholarships

Ray Hunt
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1. Executive Summary

The Irish dairy sector has tremendous potential to be one of the most sustainable sources of high quality milk and dairy products to satisfy strongly growing global demand. Irish milk production has been shown by the EU Commission's Joint Research Centre (JRC) to have the lowest carbon foot print in Europe.

Through the implementation of the Sustainable Dairy Assurance System, farmers are proving through audits carried out every 18 months on every farm that this is the case. But while Irish farmers are doing a lot of things right, they need to do more to face the challenges of sustainability, herd and cow fertility, and animal health.

This report explores the impact and measurement of genetics in dairy herds internationally and sets out to make recommendations for Ireland to improve the sustainability and efficiency of its milk production by focusing on genetics and analysing new and emerging genetic technologies.

The report also examines Ireland's Economic Breeding Index (EBI) system and outlines the effect it has had on the national dairy herd whilst also pointing to the future viability of this breeding index model.

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2. Introduction

1a. Background to my study

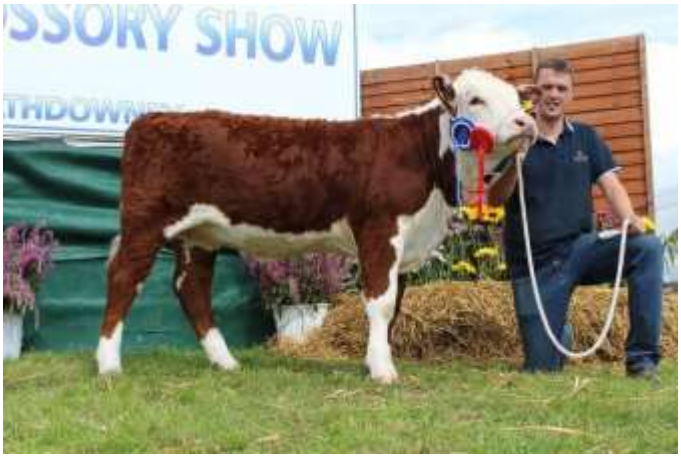
The modern Irish dairy cow is an incredible animal, extremely effective at converting grass to milk. But just like top athletes, cows must be in great health to have optimum performance. Top farmers know that prevention is better than cure and this is where genetics can play a key role too. Healthy cows make for easy care cows that lead to increased sustainability. In addition, good health traits positively impact the environment through greater efficiency and reduced costs. Cow health can be preserved and boosted in many ways. Grass based farming is most conducive to protecting the health and longevity of the typical cow. This green image also pays dividends for farmers as it is very popular with consumers too. Consumers are now more aware of what they are eating, where it has come from, where it has been produced and its health benefits. In Ireland, it is vital that we retain our clean and green image. We have worked exceptionally hard on promoting this, particularly through the brand, Origin Green. In summary, the characteristics of a healthy cow are as follows:

- Less disease
- Less use of antibiotics
- Content within itself
- More efficient
- Less pollution
- Maintains good body condition score

My Nuffield report will explore the impact of genetics in dairy herds internationally as I have seen on my Nuffield travels through my Global Focus Programme. I set out and make some recommendations for Ireland to improve the sustainability and efficiency of its milk production by focusing on genetics and investigating new genetic technologies.

My report also examines Ireland's Economic Breeding Index (EBI) system and outlines the effect it has had on the national dairy herd whilst also pointing to the future viability of this breeding index model.

3. Personal Background



My name is Ray Hunt. I live on a mixed farm of beef, sheep and dairy near Cashel in Co. Tipperary. I studied Agriculture at Third Level and achieved a Bachelor of Science Degree in Agriculture from Waterford Institute of Technology in 2005.

Subsequently, I began my agricultural career working for the Irish Cattle Breeding Federation (ICBF) in Bandon, Co. Cork. There I gained vast experience in many aspects of the livestock breeding industry, particularly in the area of genetics.

In 2007, I began working with the Munster Cattle Breeding Group and was heavily involved in their A.I. operations. Currently, I head up a team of 35 A.I. technicians based across the counties Tipperary and Clare.

In terms of my farming activities, I entered the dairy sector as a recipient of a new milk entrant quota in 2014. Initially, my home farm had been a solely beef and sheep enterprise. I milked 56 cows and this had grown to 64 cows in 2015 with further plans for expansion in the short term.

My study topic for this paper is “Future Genetic Trends for Grass Based Dairying”.

I believe that there is much to be gleaned from the best practice operating in other predominately dairy countries and am confident that the findings to be set out in this paper could positively impact the dairy sector in Ireland.

The main areas of my enquiry are:

- The benefits of genotyping dairy female cattle in Ireland.
- The impact of methane gas on Global Warming.
- The future of the Irish dairy herd.
- The emergence of gene editing and it's potential role in Irish Agriculture.
- The future of dairy genetics and the new emerging popular traits.

My Nuffield research programme began at the annual Contemporary Scholar's Conference (CSC) held in Co. Cavan in March 2016. This event provided me with a valuable insight into the Nuffield programme and afforded me the opportunity to listen to very learned speakers on a variety of interesting topics such as communication, leadership and EU Policy.

Following the CSC, I participated in the Global Focus Programme (GFP) in June 2016. This journey took in visits to Singapore, India, Qatar, Turkey, France and the USA. This was an experience of a lifetime and facilitated visits to agri-related business and Government Institutions in each of the countries we visited.

There were eight other scholars in my GFP group, from Australia, New Zealand, Canada and Northern Ireland. These scholars were from a wide range of farming related industries including: cereals, organic fertiliser, dairy, beef, sheep, turkeys and organic banana production. The different and often opposing perspectives of the group allowed me to experience first-hand the complexity of agriculture and agricultural research.

Whilst on my personal study tour in November 2016, I visited Australia and New-Zealand. I studied at several colleges, research centres and farms. My main learning objective was to examine their grass-based dairy systems and discern what type of breeding technologies could be adaptable in Ireland (if any).

4. Study Tour: India

India was one of the biggest and most influential learning opportunities during my research.

The country's population is over one billion people, which is forecast to exceed 1.6 billion by 2035. Half of the population is under 30 years of age.

With these figures in mind, India needs to effectively secure ways of feeding their growing population in the near future. There are 200 million dairy cows in India and 100 million milking buffalo. Buffalo numbers are increasing even though their milk production is roughly half the quantity of a dairy cow. The main reason for the rise in the buffalo growth is because they can be slaughtered and eaten whereas cows are sacred to the Hindu religion and cannot be. About 80% of the Indian population are Hindu.

4a. Vet and Animal Sciences

The Indian dairy industry is currently exploring ways to improve the indigenous breed (or in India known as Sahiwal/milking Zebo) of cows and buffalo. One major difficulty with the indigenous breed is that it does not reach maturity until the age of three and a half years. I believe that this is a huge cost to bear for any system due to the length of time before an income can be derived from each individual cow. This type of animal averages 5-7 litres per day with a fat composition of between 5.0 to 5.5%.

The main health problems they encounter with these cows are mastitis, septicaemia, ketosis, peritonitis and ticks, with the latter being a widespread issue in India. Whilst in the university, we discovered that modern technologies are now an integral part of communication between farmers. For example, I witnessed the use of a WhatsApp group as an effective form of communication. I learned that the most effective form of education is through peers, i.e. farmer to farmer.

4b. Amul Dairy Co-Op

While studying in India, I visited Amul Dairy. This is a co-op which started in 1946 and has continued to grow steadily since then. It services 3.6 million dairy farmers with milk coming from 18,000 villages. The cows are generally looked after by the woman of the household.

Amul Dairy has set up its own cattle breeding centre with the aim of improving the dairy genetics for their farmers. During our visit in June 2016 Amul Dairy was paying their farmers 38 rupees per litre (51-euro cent per litre). The cost of production is 15-16 rupees per litre of milk (20-euro cent per litre), and 70% of this production cost is feed.

The average herd size in the dairy catchment is 5 cows per herd. Within the catchment area there are only 35 farmers with milking machines out of a total of 3.6 million dairy farmers. The remainder are milking by hand. The average cow produces 7 to 8 litres a day and for buffalo cows they produce 3-4 litres of milk a day.

One of the big problems facing these farmers in India is that the Hindu religion does not permit them to slaughter a cow. Therefore, a cow that is no longer producing milk is a huge drain on profitability.

With an average herd size of three cows across the whole of India, there is often at least one that is infertile or not producing milk. This poses a huge cost for each farmer as this cow has to be kept and maintained without any return.

Conversely, the two cows that are milking are paying for the cow that is empty and thus increasing the cost of production for the overall herd. Within the Irish context, infertile cows are sometimes kept for a year although they are not in-calf, particularly in Autumn or Winter calving systems. From this, I reaffirmed my view on the importance of fertility and it is imperative for Irish farmers and its even greater significance for Indian farmers.

Amul Dairy found that heifer calves were not being properly reared on

farms so they introduced a scheme where the heifer calf is bought off the farmer at three months old and is then reared by Amul in a specialised dairy heifer rearing unit. Amul has found that this works very well as previously farmers struggled to get heifers in calf. This is due to poor nutrition and lack of care for heifers who are not producing milk. Milking animals are given preference, yet young females need consistent care to ensure they can produce adequate levels of milk on maturity.

4c. Key Findings

On my arrival home to Ireland, I learned that in Irish heifer rearing systems only 56% of heifers calved between the ages of 22-26 months of age. Is it possible that something similar may work well in Ireland?

I believe that many farmers fail to grasp the importance of heifer rearing. Therefore, a proper systematic approach needs to be put in place for rearing heifers, so we can achieve the target weights required in order to enable these females to calve at two years of age.

It is my firm view that there are opportunities for Ireland to export dairy produce into India. The Indian summer period would be an optimum time for this as cows produce a lot less during the summer due to heat stress.

One of the most crucial factors for any dairy company in Ireland who wants to trade internationally is getting the right partner that understands your product and is trustworthy. The current high tariffs will need to be re-evaluated for any trade agreements to work.

This could be modelled on the Australian agreement with India, whereby there are few barriers to trade. Ireland is one of the biggest providers of aid to India.

There is an existing relationship already in place, which could be developed in the form of tariff-free dairy produce. Due to India's rising population, they will require future aid both in both aid and food produce.

Beef consumption in India is exceptionally low. Therefore, I do not see prospects for Irish beef exports to India in the near future.

In Summary

- Large Cow Numbers.
- Large population and further growth expected.
- Cheap labour available.
- Heat Stress
- Cows not slaughtered due to religious beliefs.
- Disease issues leading to low fertility.

5. Study Tour: Turkey

In contrast to India, Turkey has a huge market for beef. The type of cattle that are needed in Turkey are predominately U and R grade cattle. The biggest issue in Turkey is the volatility of the Turkish lira and as a result of this, all International deals are made in the US dollar. Turkey are

paying $5 per kilo per live weight for cattle, with the farmer receiving $10 dead weight. Cattle are bought from other countries through government agencies. Farmers are not permitted to buy cattle outside of Turkey. Labour costs are 40 Turkish lira a day for women and 70 for men.

Farmers typically receive 36 cent a litre for milk in Turkey and during my study trip to the country, I had the opportunity to visit a new Turkish dairy Enterprise. This farmer was milking 80 cows and had plans to expand to 120. The cost of this new dairy facility was 1.5 million dollars, 60% of which is supported by the government. For new dairy facilities, there are good government grants that can be availed of, up the amount of 75% of the overall costs.

The cows originated from Hungary and Holland and were initially bought by the government. Mastitis was a big problem due to the elevated temperatures over the summer period. Four people were employed full time at this farm and the cows were averaging 27 litres of milk per day. from an average herd size of just 10 cows.

Milk Production in Turkey

There are 14 million cows in Turkey, owned by a combined pool of 1.5 million dairy farmers. I found that dairy herds in Turkey have a huge problem

with fertility. The average cow is completing just two lactations. This is unacceptable and is due to a combination of things such as; poor breeding, diet and the extreme heat.
As a result of this I see potential for high fertility genetics to be used in Turkish dairy herds and Ireland is well placed to help alleviate this issue through the supply of AI straws from fertile and long lasting cow lines.

Turkey imports 4 million doses of semen for their dairy herds from all over the world.

5a. Sütaş Dairy Brand

	2015 Market share
• Sutas	16%
• Brand	10%
• Brand	5.8%
• Brand	3.4%
• Brand	3.2%
• Brand	3.1%
• Brand	2.5%

Sütaş is the leading brand in Turkish dairy sector for the past 11 years. It reaches 80% of the households in Turkey.

There is an effort to portray an image that milk is produced from cows that have access to green pasture. However, it appeared that most herds are fed on maize silage.

In Summary

- 75% start-up grants available for new dairy entrants.
- Cheap labour available
- Poor Fertility
- No breeding plans / objectives in place
- 2 year average lactation.

6. Study Tour: New Zealand

I travelled to New Zealand on my Global Focus Programme. There are similarities and differences between the Irish and New Zealand dairy industries. Similar in the importance of the dairy industry to both economies and the grass based production system, and differences in the way that both have evolved since the 1980's.

In recent years the industry has faced the issue of the welfare of bobby calves, and is addressing this.

The landscape/ topography of farms in New Zealand is also very different to most of our dairy land in Ireland. In many parts the land is hilly in New Zealand. While it is a grass based dairy system, the crossbred genetics seems to work well here due to the hilly conditions and vigour within the crossbred dairy cow, which is not only high in solids, but being of a smaller build can graze the hilly grasslands

Irrigation of land for dairy has become more popular within the last 10-15 years. Some parts of New Zealand experience droughts and the cost of the irrigation systems can be a huge effect on a start-up dairy.

The crossbred cow is not only high in solids, but being of a smaller build can graze the hilly grasslands.

6a. Breeding the NZ way

Semen and seed are vital inputs for livestock farmers (genes and grain seeds) and are the undeniable link between all involved in the business of farming. There has only been a 1% increase in genetic gain in pasture over the last 20 years. There has been half the gain in pasture in comparison to animal genetic gain.

I was fortunate enough to visit CRV (Ambreed). Peter van Elzakker pointed out that nitrate leaching as one of the biggest issues going forward for farmers. He also explained that each County Council area has its own laws regarding nitrates.

Genetics is all about the future and tries to point out the genetic gain that can occur if genetics are used correctly and judiciously. Peter also commented on the fact that some cows never reach their full genetic potential. One reason for this, according to

Peter is that cows aren't been fed adequately.

He went on to tell me about the usage of different breeds in their company.

- Holstein/Friesian 50%
- Crossbred 28%
- Jersey 13%
- Other 6%

Regarding the 6% in the "Other" bracket, this section has been growing by 2% year on year. This is due to the fact that more beef is now being used on the dairy herd. Over the last number of years cow numbers have increased dramatically but have now reached the ceiling of growth, with numbers expected to level out.

With this growth grate in mind we decided to visit one of the beef herds where CRV source most of their genetics from. This herd is a pedigree Hereford herd and is located south of Christchurch. It is operated under the pedigree prefix of Bluestone Herefords.

The Bluestones neighbouring farm is also a pedigree Hereford farm called Shrimptons Herefords. Both Bluestone and Shrimptons breed for similar traits in their Herefords. However, the biggest trait is their short gestation length.

Bluestone supply CRV with their genetics and Shrimptons supply LIC. LIC have trademarked their semen with Shrimptons, and it is now all known as SGL semen. (short gestation length). By doing this, no other semen company can call their short gestation semen SGL. Shrimptons Herefords choose 7 bulls each year to draw semen for LIC. These bulls are chosen through their data for easy calving and how short their gestation length was.

SGL semen has been selectively bred from certain genetics in order to shorten gestation length which in turn shortens the calving period, increases days in milk and gives cows longer to recover post-calving, giving them a better chance to get back in calf. Calving ease are estimates of genetic differences in the ability of a bull's calves to be born unassisted from two year-old heifers.

Whilst low birth weights help the ease of calving and the gestation length they are also associated with lower overall growth potential. Consequently, birth weight and growth need to be carefully balanced. Most SGL semen used does live up to its expectations, allowing 10 days shorter gestation, which would benefit the farmer with more milk and thus increases the profitability of the herd overall.

Short gestation length semen is used only for achieving short calving intervals and is not effective for breeding replacement heifers. The bulls that are used to provide the SGL semen have a -20 day calving interval and when mated with a normal gestation cow will give you a -10 day gestation length.

Short gestation semen could help some Irish farmers if they are planning to calve their herd in a compact way and would also bring late calving cows forward. However, with the birth weights affecting growth performances it would most definitely affect the beef trade here in Ireland too. With the amount of Hereford calves on the rise within the dairy herd, if SGL Herefords were to be become more popular here in Ireland farmers might think twice before purchasing Hereford calves to rear/finish due to these slow growth rates.

6b.The Five Production Systems

The Five Production Systems are a way to group farm production systems by allocation of imported feed.

As New Zealand pastoral farming is about profitably balancing feed supply and demand, five production systems have been described by DairyNZ, primarily on the basis of when imported feed is fed to dry or lactating cows during the season and secondly by the amount of imported feed and/or off farm grazing. The definitions do not include grazing or feed for young stock.

System 1 - All grass self-contained, all stock on the dairy platform No feed is imported. No supplement fed to the herd except supplement harvested off the effective milking area and dry cows are not grazed off the effective milking area.

System 2 - Feed imported, either supplement or grazing off, fed to dry cows Approx 4 - 14% of total feed is imported. Large variation in % as in high rainfall areas and cold climates such as Southland, most of the cows are wintered off.

System 3 - Feed imported to extend lactation (typically autumn feed) and for dry cows Approx 10-20% of total feed is imported. Westland - feed to extend lactation may be imported in spring rather than autumn.

System 4 - Feed imported and used at both ends of lactation and for dry cows
Approx 20 - 30% of total feed is imported onto the farm.

System 5 - Imported feed used all year, throughout lactation & for dry cows
Approx 25 - 40% (but can be up to 55%) of total feed is imported.

*Note: Farms feeding 1-2kg of meal or grain per cow per day for most of the season will best fit in System 3.

At New Zealand Dairy I found out the milk solids production has increased by about 50kgs/cow over the past 10 years. It is estimated that 42% of those production gains are from genetic improvement.

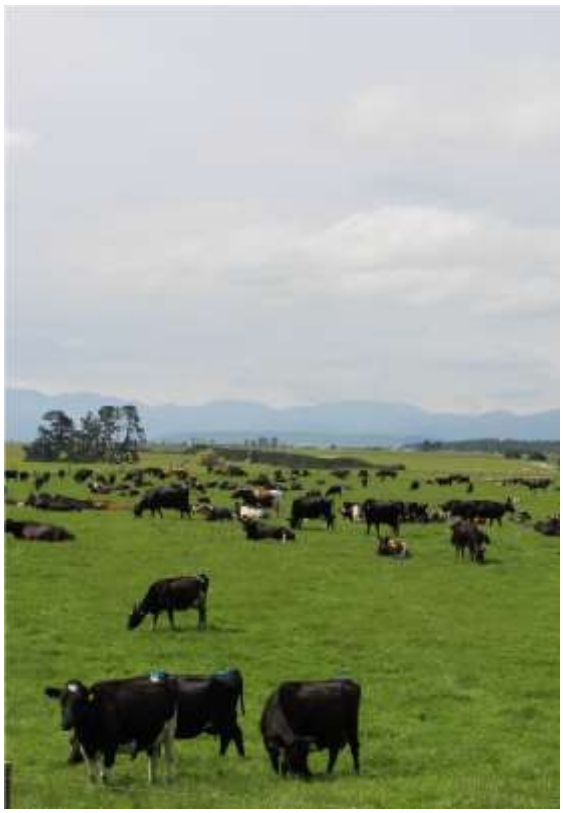
6c. Issues I see going forward in New Zealand

- Access to water for irrigation a big issue for further expansion.
- Bobby Calves – the status of the male calf needs to be improved. It may be that farmers may have to rear bobby calves until they are at least 100kgs. This would add cost to the system.
- Fertility is becoming an issue & New Zealand farmers are struggling to get a calf per cow per year. This has an impact on efficiency.
- The ending of fixed milk pricing in NZ is a potential challenge for farmers. Farmers on tight margins which are highly geared and fluctuation in price is detrimental to repaying debt.
- Bigger farmers find themselves in a position of managing people & not cows. This is becoming more of the norm in Ireland now and farmers need to develop this skillset.

6d. Ryan O'Sullivan (New Zealand dairy farmer & Nuffield Scholar 2017)

Ryan is milking 1250 cows on 900 Ha. He oversees the running of the farm and has one labour unit per 250 cows, with some additional casual labour. They work a rota of 11 days on with 3 days off. Cows are grazed 365 days of the year, which includes some winter forage (fodder beet & Kale).

Each cow currently produces 490 kgs of milk solids on the back of an average 1.4km daily walk to the milking parlour. Six weeks of AI is used with 60% of the bulls used Friesian and the remainder cross-bred.



If farmers producing crossbred bull calves are encouraged to rear these bull calves to 100kgs, this would certainly impact on the extra profit cross-bred herds are making.

New rules have recently come into force where bobby calves must be provided with shelter that keeps them warm and dry, and loading facilities that allow them walk onto the trucks.

These regulations are ultimately protecting the welfare of calves. There is ongoing work to be done for the bobby calf industry, which will eventually counter the images being portrayed in the media.

6e. Bevan Harris LIC Geneticist

In light of my keen interest in genetics, I had to visit the leading cattle breeding company LIC, where I was fortunate to meet Bevan Harris.

He explained that the price of milk in New Zealand was starting to improve and is now $6 a kilo of milk solids. Last year milk prices were poor and LIC made a loss of $5 million dollars.

Conversely, when milk prices were good LIC made profits in excess of $20 million. Out of a total pool of 12,500 dairy farms in New Zealand LIC holds an 80% market share from the entire country.

LIC also carries out 85% - 95% of herd testing (milk recording) and collection of other breeding data and information. In New Zealand, there is a huge emphasis on milk solids and the beef market is definitely plays second fiddle to the dairy industry.

Tall Holstein Friesian type cows are not suitable for the current market and live weight per kilo of milk solids is a key performance indicator on a New Zealand system. Other key performance indicators are in-calf rate after two cycles (42 days or 6 weeks in calf rate).

Bevan explained that New Zealand farmers find it easier to get a 400-kilo live weight cow to produce 400 kilos of milk solids than a 500-kilo cow producing 500 kilos of milk solids. The percentage of feed that is pasture based is another factor for consideration.

This is of high importance as many farmers could achieve this goal by feeding extra concentrates albeit at an excessive cost which would make these animals inefficient converters of milk solids. Crossbred bulls have a huge part to play serving 50% of maiden heifers and these bulls are used mostly for ease of calving.

LIC uses their national database to make breeding decisions and to select potential

AI sires. 2000 male calves are chosen on their BW and are genotyped, these samples are sent to the USA. It takes 10 days for the samples to be received by the US and 2 and a half weeks for the results to be received. From this 180 bulls are purchased. The breakdown of these bulls are as follows,

- 70 crossbreds
- 70 Holstein Friesian
- 40 Jerseys

Over 100,000 females have been genotyped to date by LIC. In addition to this 12,000 males have also been genotyped.

This was done to receive more accurate information on genetics but has been put on hold for the time being due to lack of funds. Disease and heat tolerance have been investigated closely with heat tolerance playing a key role in the viability of the emerging export market of cattle to countries in South America, Africa and Asia.

Ticks and other heat seeking insects and parasites can play havoc with cattle in warmer climates and animals with a higher level of heat tolerance can better deal with these humid living conditions. Heat tolerance can now be detected by using thermal imagery.

Bevan also explained the key elements of the Breeding Worth (BW) programme in New-Zealand. The BW index ranks male and female animals for their genetic ability for breeding replacements. The BW has been developed to include a lot to functional traits such fertility, Survival and conditional score.

Two cow indexes have been amalgamated into the BW scores in recent times, including:

1) The Lactation Worth (LW). This index ranks female animals for their current season performance. The LW is calculated on a dollar basis for the cows own milk, fat, protein, milk volume and live weight for its current lactation.

2) The Production Worth (PW). This index ranks female animals for their lifetime performance. The PW is therefore calculated on total performance rather than one single lactation.

I was very impressed with both the PW and LW ranking used to evaluate cow performance in New Zealand. Both of these indexes were used to form the basis of farmer culling decisions.

Something similar would work well in Ireland and is an area, which should be more fully explored by ICBF and dairy farmers in Ireland. Upon my return, I investigated if there was any such index that was being worked on in Ireland.

An ICBF geneticist, Mags Kelleher has started a pilot project with a new index for dairy cows called the Cow's Own Worth (COW).

Mags explained to me how her trial had gone so far and that she was planning to roll it out to all Spring Calving Calving herds in September 2017.

David Sellers, Genetics Consultant at LIC in NZ, gave me a tour of the facilities including the semen collection area. This proved to be a very interesting experience, and he gave me an insight into their semen programme. Fresh semen is collected in the early mornings, daily, during their peak season.

Demand for semen in peak breeding time is such, that this semen is flown from the north island in Hamilton to the South Island for distribution. LIC send out a minimum of 100,000 straws every day during their peak.

David has noticed an increase usage of A2 type bulls and the company is now selling over 200,000 doses of A2 bulls per annum.

Another key insight from my research trip to LIC is that fact that the population of Jerseys in NZ is decreasing. This is validated by the fact that although LIC genotype 2,000 males calves each year (of which 180 bulls are selected), the breed breakdown for this is 70 x-bred, 70 FR & 40 Jersey which shows a marked decline for the Jersey in comparison with the other major dairy breeds. BW has moved a lot to functional traits – Fertility, Survival & Condition Score.

LIC has Genotyped 100,000 females but have scaled this back for the moment, due to budgetary controls, (last year LIC lost $5 million in comparison to the year before where they made a profit of $20 million). Bevan feels that cow numbers will not rise in NZ any further but genetics will improve overall milk solids.

6f. Dairy NZ

Dairy NZ is the farm advisory organisation that provides research and services, education and policy and dairy industry strategies and is operated in a similar format to Teagasc in Ireland.

While I was there I met Dr Jeremy Bryant, Manager of Animal Evaluation Ltd, which is a subsidiary of Dairy NZ, and he gave an insight into the activities and research currently being carried out.

Cow evaluations are produced by Dairy NZ, but LIC has the rights to sell the BW and genetic information. Jeremy feels that

farmers have paid for their genetic elevation and those farmers should take precedence to ownership of the evaluations and not LIC.

This highlighted for me the advantage we have in Ireland, whereby ICBF do all genetic evaluations on behalf of the Irish farmers. It is very important for us to keep this information in the ownership of farmers and not let any company with any financial vested interest take control of this data.

In Summary

- Grass based simple system
- Breeding company owns the database
- Good grass based genetics
- Fertility becoming more of an issue
- PW index working well (cow)
- Bobby calf problems.
- SGL beef working well.
- Poor water supply in certain areas.
- Nitrates becoming an issue.

7. Study Tour: Australia

7a. Brisbane

I met with Professor Prof. Ben Hayes of the University of Queensland in Brisbane, who is one of the world's leading researchers on bovine genetics. He believes that genomics has come a long way and will evolve and dominate the market in the future. He mentioned a number of new technologies that he feels will be essential to the bovine industry. These include:

1. Genomics
2. IVF technology
3. CRISPR technology
4. Sexing technology
5. Crossbreeding

We discussed CRISPR and the role he thinks it will play in the dairy industry. He spoke of his excitement about CRISPR, but warned of its potential pitfalls.

First, we have to ensure that the consumer is educated on what CRISPR is and how it works and is even more important that is it not associated with genetically modified products.

For instance, goats born with the polled gene are infertile and if using When using CRISPR as part of a sexing programme, it is extremely hard to identify the x and y chromosomes. He pointed out that nature does not want more males or females in any given plant/animal/species. Nature will fight against it and it one of the few universal truths that nature can be one of the hardest things of all to fight against.

When I asked about gene editing and if it was possible to produce a bull that could only produce female semen his answer was "It could be achieved and I reckon that it is being carried out in other countries, however, it is illegal in most countries at this moment. But if it was to be achieved, testing for gene editing is almost impossible and it is possible for freak genes to occur in some animals".

From this I learned that Ireland must not be left behind, it is important for us to keep up with this latest technology so that we can maintain our competitiveness in the global market place.

7b. CSIRO

Whilst in Australia, I met with Dr. Jen Taylor and Dr. Mick Ayliffe in the Commonwealth Scientific and Industrial Research Organisation, which operates from the Federal capital in Canberra. The CSIRO was set up in 1916 and their mission statement sums up the company's objectives perfectly:
"At CSIRO we do the extraordinary every day. We innovate for tomorrow and help improve today – for our customers, all Australians and the World".

Jen explained that CSIRO is Australia's largest patent holder. Over the past century they have been pushing the boundaries of innovation through science and technology.

Some of their world-renowned success stories include Wi-Fi, the Hendra vaccine and polymer banknotes. These achievements aside, the main reason I was there was to find out further information on CRISPR technology. Dr. Ben Ayliffe explained CRISPR technology to me and how it can be effectively used, in conjunction with Gene Editing technology.

What is CRISPR? (Clustered Regularly Interspaced Short Palindromic Repeats).

The term is unfamiliar to most people involved in the dairy industry but Ben believes that this will change quite quickly. Ben proceeded to tell me that CRISPR is a new way to edit genes and can go above and beyond what the traditional GMO techniques can do.

The main point of differentiation from the CRISPR technology and other forms of genetic modification is that by using the Cas9 enzyme, it mirrors a process which occurs naturally in nature. CRISPR has the ability to edit and rearrange genes, by cutting out part of the DNA that is damaged or unwanted, allowing the remaining DNA to be re-arranged in a new way.

Because this method is built on natural principles, it is likely that CRISPR may not be subjected to the same levels of

regulation as GMO technology has been.

Ben showed how it can be used in a targeted and precise manner. I was amazed to find out that Mutation breeding has been around for a long time using chemicals.

Ben said that using CRISPR is a far more efficient way of finding the Genes you are looking for and is far safer for wholesale usage.

However, it is important to stress that caution is needed as Off Target Effect can occur if the sequence you're looking for in the Genome has a very similar mutation elsewhere.

If you look at the background rate of which this occurs in plants where your just blasting the whole Genome with all these mutations it's just trivial.

The Office of Gene Technology recently put out a call for submissions on the technology.

They may update the legislation so that CRISPR can be used. Current legislation was passed before CRISPR was discovered. Australia, like Ireland, needs to be careful with this legislation as we are major exporting countries and that the same legislation is in place in the countries we export to. CRISPR is currently more popular around the world in animals than in plants.

There is also huge interest in CRISPR in human therapies. For example, with a cystic fibrosis gene it is possible to cut that gene and put in a repair template. This can be done at the embryo stage or with stem cells at any stage. This could make humans disease free in future.

Dr. Ming Lou, Biologist at CSIRO, explained that a study on seaweed diet in animals has been undertaken and the results were incredible.

He explained that red algae produces a chemical, bromoform, and when consumed by animals reduces methane production by 70%.

By changing an animal's diet by 1% it will reduce emissions by up to 70%. This finding has staggering implications for the modern dairy industry, across the world, but particularly here in Ireland where we are currently behind our emission targets for the EU.

In Summary

- Three different indices.
- Some good grass growing regions.
- Poor fertility.
- Not maximising their competitive advantage.
- Farms can be socially isolated.

8. Study Tour: USA

When I visited the USA I learned that the USDA had decided not to regulate the use of CRISPR for the design of a white mushroom button variety which would resist browning. Subsequently they clarified that other CRISPR edited plants such as corn, soybeans tomatoes and others would be free from some of the red tape associated with GMO's. This strategy is now happening in other countries. The director of the Swiss Institute of Organic farming has made a statement in favour of CRISPR, shocking many NGOs and lobby groups of organic agriculture.

So now the BIG question is, can CRISPR succeed with consumers where GMO's have failed? First of all we must separate the two of these.

If CRISPR is to succeed, people need to understand it before reaching conclusions. CRISPR is a proven technology and countries will not want to be left behind. CRISPR organism costs 1% of a GMO, and can be brought to the market place in a tenth of the time.

The USDA is currently doing a lot of work on genomics. Their objective is to target and identify individual genomes that carry certain diseases. With the evolution of gene editing they can see advantages in editing certain genes rather than having to vaccinate animals against these diseases, which costs the farmer money.

The USDA is looking at genomic information on feed intakes, which is an area in which Ireland will be interested.

9. Study Tour: Ireland

9a. EBI

The EBI formula was introduced in 2001 through a joint venture by ICBF and Teagasc. In the intervening years, the index has evolved to incorporate some 15 individual health and production traits in total.

The most important of which are female fertility, cow survival and milk solids production (kg fat and protein). These traits have a combined weighting of about 70% of the overall index.

(Teagasc "Todays Farm" July August 2017).

- Each unit in herd EBI translates to €1.946 profit per lactation in Holstein Friesian cows.
- Animals with a higher maintenance sub index (i.e. genetically lighter) are indeed lighter animals.
- Progeny from sires of higher genetic merit for milk production and composition do indeed produce more of greater composition.

Proof of the validity of the EBI formula:

At the National Dairy conference (ref), Teagasc compared the performance of 10,470 dairy herds that had herd EBI, female fertility and milk co-op performance data available. The data was from three sets of ICBF Herdplus reports that had been posted to herdowners in the previous months. These were:

1. Herd EBI report
2. Herd Calving & Fertility Report
3. Herd Co-op performance report

(based on the nine month period from Jan to Sept 2015).

Herds were categorised on the basis of herd EBI level. They were divided into ten evenly spaced categories such as:

- the top 10% of herds (some 1,047 herds in total), had an average EBI of €176,
- the medium 10% category had an EBI of €135, and
- the bottom 10% of herds had an EBI of €63.

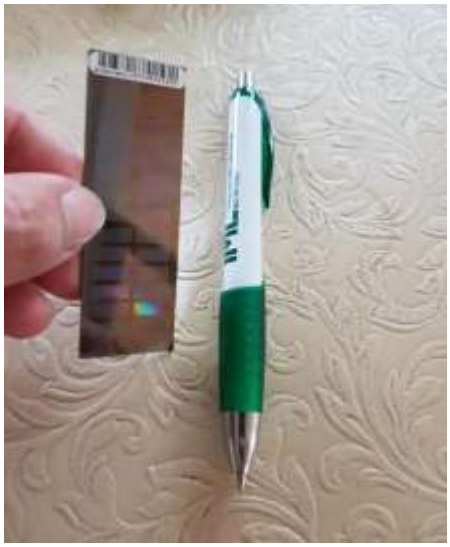
9b. Genomics

"Genomics is the study of an animal's DNA or 'Genotype' (usually a tissue or hair sample)." (ref)

Genotypes are made up of Single Nucleotide Polymorphisms (SNPs). These are a DNA sequence variation

occurring commonly within a population and each SNP represents a difference in a single DNA building block, called the nucleotide. Chips used in genomic testing can vary in size and can have various numbers of SNPs. DNA is transmitted in chunks and genomic testing then identifies which DNA chunks have been passed from the parents to its offspring.

Here is an example of one of these chips I received from Dr. Donagh Berry (Teagasc Moorpark).



Genomics has grown in popularity in Irish cattle breeding and continues to improve its accuracy levels (ref).

On 31st May 2017, ICBF passed a major milestone with over 1 million cattle displaying a valid genotype. Ireland is only the second country in the world to surpass this achievement, with the USA crossing the 1 million mark in 2016 for dairy cattle. Ireland also contains the world's largest genotype database for beef cattle with over 894,000 genotypes collected to date. No other country has this level of its national breed herd genotyped (ref).

This level of genotyping allows Ireland to have an extremely accurate and detailed insight into its national pedigree herd, which is of utmost importance for genetic analysis into the future. The analysis of newly reported genetic traits and defects serves to help aid the reduction of genetic disease risk, and provision of insights into the genomics of fertility, feed efficiency, and disease resistance.

Overall, this level of genotyping will allow Ireland to have a major impact on food sustainability, farmer profitability and environmental impact.

Firstly, the genotype is studied to confirm parentage. This ensures that the dam and sire recorded are correct and adds reliability to any data collated.

Secondly, genomics then examines an animal's traits (milk production, carcass weight etc.). The genomic sample is compared to the genomic samples of progeny proven animals (100K+ proven

animals). Animals that are superior on certain traits will be identified through their genotype sample before any performance data of their progeny has been recorded. This allows herd-owners to make proactive decisions when deciding which animals should be kept as herd replacements or as potential stock bulls.

When an animal is genotyped all traits are studied (including those mentioned above), and this genomic information is then added to the phenotypic data (traditional data) and an index with more reliability is then formed as a result. Genomics includes the DNA of an animal (from tissue, hair, blood or semen) in addition to other performance data on relatives, in its EBI/Eurostar calculation.

Advantages of Genomics:

Higher reliability EBI: Genotyping increases reliability % figures even before the animal has produced any offspring.

Parentage verification: A genotyped animal can have its sire & dam confirmed.

Breed verification: Genotyping will be able to identify an animal's breed make-up.

Genetic diseases: An animal's carrier status for a number of diseases and major genes (e.g. Myostatin) is also possible.

Traceability: Genotyping ensures that from birth there is full traceability of every meat sample directly back to the animal. (This can also help reduce cattle rustling as all animals can now be traced back to the farm of origin).

Genetic Gain: This helps to increase Genetic gain due to bulls receiving a more reliable index at 6 weeks of age.

9c. Main limitations of EBI formula

I met Teagasc Geneticist, Donagh Berry, who discussed the main limitations of the EBI formula in its current state. The areas discussed and analysed were:

1) Feed intake & Efficiency
2) Environmental Footprint
3) Product Quality
4) Health & Disease (Although already in the index he believes that it is poorly represented.)

Feed Intake & Efficiency:

Efficiency is the relationship between input and output, e.g. the dry matter consumed versus milk produced by the cow. Energy is needed for maintenance

and production. Donagh explained that a good proxy for feed efficiency is

Feed intake and efficiency are 30-40% heritable. 30% of the differences in feed intake with a group of similar managed cows are due to genetics. Feed intake is very hard to measure and very expensive to do so.

The only way to accurately measure feed intake is on an indoor-based system. It is almost impossible to measure feed intake on a grass-based system as the cows are in a different environment socially and would also be competing for food.

Every year in Ireland over 600,000 cows are milk recorded. In order to collect accurate and reliable date, the same number of cows would need to be recorded in terms of their daily feed intake.

Currently, Donagh Berry is working on a way in which feed efficiency can be calculated through milk samples. It is an equation that can estimate feed intake and energy balance. This would be of value to farmers as information could be provided through milk samples every second day from the bulk tank and every month from milk recording.

increasing milk solids and reducing live weight.

Environmental Footprint

Other aspects of sustainability are CO2 emissions and nitrate leaching from cows attracts an even higher importance.

One comment from Donagh Berry stood out. “Genetics creates potential, management realizes the potential and Disease destroys it”.

Product Quality:

This is vital from an Irish standpoint as 90% of our milk production is exported. The global population is increasing and many more people are better educated and affluent.

Therefore, they are choosing carefully the products that they are purchasing. Most of the milk produced in Ireland comes from grass fed cows which is higher in Omega 3.

Sexed Semen

I met Steven Butler, Research Officer - Reproductive Physiology & Systems Biology at Teagasc Dairy Research Centre in Moorepark to discuss the

merits of sexed semen and how it can work effectively on an Irish dairy system.

Sexed semen is available in most countries around the world, and is primarily used in dairy cattle breeding. Sperm is taken from an AI bull and is sorted by flow cytometry.

Despite reliably producing 90% gender bias, the fertility of the sexed semen product has a lower conception rate than conventional semen. The negative implications of the reduced fertility of sexed semen are amplified in seasonal systems of the dairy production, as the importance of fertility is a lot greater in these systems compared with year-round calving systems.

A large-scale field trail was carried out in Ireland in 2013 which suggested fertility of sexed semen is 87% as good as conventional semen. This trail occurred four years ago and there have been improvements in sexing technology in that time.

In Summary

Advantages of sexed semen	Disadvantages of sexed semen
• Increased number of female calves	• Lower conception rate
• Less dairy type bull calves	• Sexed semen is more expensive
• Heifers born at start of calving	• Less bulls to choose from
• More short gestation beef bulls can be used	

9d. Crossbreeding

The value of crossbreeding

Many studies undertaken at Teagasc Moorepark over the past 10 years have shown improved animal performance among high EBI crossbred dairy cattle when compared to purebred contemporaries. They have quantified the value of this benefit to be €100-€150/lactation.

- The earliest research was conducted at Ballydague research farm during the period 2006 to 2010. This study included both pure bred Jersey and Holstein-Friesian in addition to crossbred cows. Clear benefits from crossbreeding were observed. The proportion of cows pregnant to first service (+ 21%), in-calf after 6 weeks breeding (+19%) and in-calf after 13 weeks breeding (+8%) were considerably higher for the Jersey × Holstein-Friesian compared with Holstein-Friesian (and pure Jersey cows). The economic analyses [incorporating differences in cull cow and male calf value] showed that with a fixed land base the herd of Jersey × Holstein-Friesian cows was 48% more profitable than a herd of either of the parent breeds. On a per cow basis, the improved profit equated to over €180 per cow per lactation.
- At Clonakilty Agricultural College, the trial included a comparison between Jersey × Holstein-Friesian and straight Holstein-Friesians. The EBI of both groups is again similar (€177 and €175). This study has also run for 3 years to date. The Jersey crossbred cows are delivering more milk solids per cow per lactation (457 kg vs 449 kg). They were 10% lighter (-54 kg), had 18 percentage unit's higher pregnancy rate to first service and 10 percentage units higher 6-week in-calf rate.
- An analysis of 40 commercial dairy herds with data from 2010 to 2012, represents the first evaluation of crossbred and straight bred cattle within commercial high EBI dairy herds, and again the results are consistently in line with the research findings from Teagasc research herds: high EBI Jersey × Holstein-Friesian cows produced 25 kg milk solids per cow year more than the mean of high EBI purebred Holstein-Friesian and Jersey cattle. Moreover, the crossbred cattle also achieved a 7.5-day shorter calving interval compared

to the purebred contemporaries within these herds.

- A similar piece of research conducted during development of the 'Culling' or 'COW' index found that crossbred cows had a 9-day shorter calving interval, a 6% greater pregnancy rate in the first six weeks of the breeding season, and a 3% greater survival rate to the next lactation. Lifetime financial heterosis was estimated to be just under €550.
- This research study at Ballydague also identified an advantage by way of intake capacity with the Jersey breed. Jersey cows consumed 4% of bodyweight in grass DM/day. This compared to 3.4% for the Holstein/Friesian and 3.65% for the Jersey crossbred cows. The importance or value of this trait is not appreciated in practice by many at farm level.

This trait is critical to the high productivity per unit area achieved with the Jersey and Jersey crossbred cows in the studies outlined above.

Detailed anatomical investigations conducted on animals post-slaughter, revealed the physiological mechanisms underpinning the differences in intake capacity observed, which tended to be more physical in nature than metabolic. Selection within the Holstein-Friesian breed using EBI will inevitably improve fertility and longevity, but not this unique capability.

The research evidence from Moorepark and elsewhere shows that High EBI crossbred dairy cattle outperform high EBI purebred contemporaries both within research studies and on commercial dairy farms because of lower replacement costs and greater herd productivity.

On that basis, dairy herds which combine high EBI Holstein-Friesian and high EBI alternative breeds will continue to reap the added benefits of crossbreeding in addition to the benefits of genetic progress in EBI.

I believe that crossbreeding has a place in the Irish Dairy Industry. From my travels and studies abroad, I understand the advantages of heterosis which is the cornerstone of effective cross-breeding.

In order for crossbreeding to work effectively, one must use a breed that has a high genetic merit index. There is no point crossbreeding with a

breed with a low index as the resultant offspring will not benefit from a higher genetic potential that its parents. Regardless of the breed used, it is imperative that you use a breed that is going to compliment your original breed and give you a high heterosis effect.

9e. Future cows

Next Generation Herd (NGH)

A good place to start the discussion on the future Irish dairy cow is the Next Generation Herd (NGH) in Moorepark. The NGH was established as a strategic resource to validate that genetic selection using the EBI will deliver under intensive grass based systems.

The goal of the EBI is to identify animals whose progeny will be most profitable under future Irish production systems. Analysis of commercial farm data indicated that each euro increase in the herd EBI results in a €2 increase in profit per cow per lactation.

The incorporation of genomic selection into national breeding since 2009 has accelerated the rate of increase in EBI significantly. The next generation herd was established as a strategic resource to validate that genetic selection using the EBI will deliver under grass based systems.

It will also enhance the future development of their EBI and provide a nucleus herd to supply gnomically selected bulls to the national breeding programme.

I met with Frank Buckley who is head of the NGH in Moorepark. He explained to me that the NGH was set up in 2012. Maiden heifer, in calf heifers and heifer calves were sourced from commercial dairy herds all over the country and from within Teagasc dairy herds.

Prior to purchasing, these animals were subjected to genomic testing and rigorous health screening. There are two distinct EBI groups: 90 elite (extremely high EBI 154 (ICBF, May 2017)) and 45 national average EBI (na:EBI 51) females.

The herd is exclusively Holstein-Friesian. Based on EBI for Ireland, the elite females are firmly inside the top 1%.

During the first three years, two EBI groups were evaluated across three contract seasonal pasture-based feeding treatments:

1. Intensive grazing
2. High stocking rate with tighter grazing residuals
3. Intensive grazing, with additional concentrate of four kgs of concentrate feed offered throughout the lactation.

It was interesting to note that the National Average Herd consistently outperformed the elite herd in terms of milk volume.

However, the Elite cows had higher milk solids yield due to higher milk fat and protein content.

On average, per lactation, the elite cows were slightly lighter but had significantly higher body condition score.

It was made clear to me from this that the EBI is working in this system.

NHG Statistics (O'Sullivan et al 2017)

	EBI	Sub-Indices (€)						
		Milk	Fertility	Calving	Beef	Maintenance	Health	Management
ELITE	154	37	80	33	-12	13	1	2
NA	51	17	13	26	-8	2	1	0

	Milk kg	Fat kg	Prot kg	Calv Int	Survival
ELITE	-18	+7.2	+4.2	-4.2	+2.3
NA	+46	+4.1	+2.5	-0.9	+0.2

10. Results

I found one of the most significant results from this study was the national average cows out yielded the elite cows in terms of milk volume, however the elite cows had higher milk solids due to higher milk fat and protein content. (See Table 2). Somatic cell count was 116,000 cells/ml and 130,000 cells/ml, incidence of mastitis was 9 and 14% annually, lameness was 9-11% annually, on average over lactation the elite cows were slightly lighter but had significantly higher body condition score. Feed intake did not differ but fertility performances were incredibly sensitive to changes within the genetic groupings as can be seen below in Table 2

Table 2

	Elite	NA
Milk Yield (kg/cow)	5413	5612
Fat (%)	4.47	4.19
Fat (kg)	241	235
Protein (%)	3,.72	3.55
Protein (kg)	202	199
Average Body Condition Score (1-5)	2.92	2.74
Average Weight (kg)	500	506

6 week in-calf rate (%)	73	58
12 week in-calf rate	92	81
Net Profit per cow (€)	844	622
Net Profit per HA (€)	2322	1709

11. Discussion

The establishment of the next generation herd represents a futuristic national herd, typical of the average Irish dairy cow. It is a strategically important resource and provides many key insights into the direction and future of the Irish dairy herd.

Therefore, the research provides a future-view of the performance implications of high EBI herds under varying grazing strategies.

Results are very promising. Performance differences are in line with expectation based on EBI. This points to the delivery of more profitable dairy genetics.

The results provide confidence that the EBI is working to identify more profitable dairy genetics and Irish dairy farmers must continue to work hard to use this data to improve their herd's genetics.

The key finding coming out of this data and research is the critical importance of fertility.

I believe that through fertility we can improve the viability and productivity of the Irish dairy herd by actively increasing the genetic capabilities of the national herd.

For example, the change from 4.0 lactations to 5.5 is significant if we were to consider this difference in human years. Let 1 year in cow years equate to 15 years in man years. This means that cows are currently living for up to 60 years and we are aiming for them to push their lifetime to 75 years.

As a consequence of ageing population, there are increased walking problems e.g. (hip and knee), more heart disease, and longer working life. Therefore, there may be effects and consequences to increased longevity.

Climate change targets set out by the EU shows that Ireland in its current projections will be 12 to 14 million tonnes of carbon above its agreed target. At €40 a tonne this means Ireland will have penalties of €1 billion in 2020. Due to the forecast of the increase in cow numbers, this figure will be a lot higher by 2030.

The average herd size in Ireland has increased from 54 in 2005 to 76 in 2016 with 50% of herds over 100 cows. This has huge implications for Ireland and its contribution to the global agricultural industry. (Ref)

12. Conclusion

My research consistently found fertility to be the biggest issue facing the modern dairy farmer, regardless of the country of origin.

Fertility continues to receive greater recognition as one of the main drivers of sustainability and efficiency in the modern agricultural climate.

Ireland has worked hard on this trait since the establishment of the EBI in 2001. The EBI has proven itself through the Next Generation Herd, and also through the assimilation of data provided by farmers to the National database.

Health was identified as another key trait that warranted special attention. Cows are living longer and subsequently healthy, robust, trouble-free cows are more desirable.

Good breeding strategies should always endeavour to improve on the previous generation and continually strive to achieve optimum performance. Our breeding objective must always be balanced and justifiable.

13. Recommendations

1. The Department of Agriculture must insist that farmers keep disease records, such as lameness and mastitis, as part of any future dairy schemes.

2. Crossbreeding has a place and should be considered by farmers with poor fertility provided the breed they are crossing with has a high EBI index.

3. More farmers must be encouraged to milk record. Without records we can't make accurate breeding or culling decisions.

4. Selective dry cow therapy is a must for farmers going forward and should be encouraged by Dairy Processors.

5. Teagasc and the A.I. industry should initiate a move to establish a sexed semen lab in Ireland. I believe another sexed semen trial at this stage would be very beneficial.

6. New technologies, such as Gene Editing, must be tested in Ireland. Gene editing has endless opportunities and we must not be left behind in testing this revolutionary technology.

7. A proper system must be put in place for matching Dairy Farmers with Contract Rearers for their calves. There must be a clear and concise agreement with monthly weight targets.

8. Beef breeders must look at the expanding dairy herds as an opportunity to breed Short Gestation Beef bulls.

9. Cows Own Worth should be used by farmers to make culling decisions into the future.

10. We must get more information on cow live weights so that we can reduce weights whilst also increasing kgs of milk solids thus creating a more efficient conversion of grass to milk.

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