Genomics in Australia

A study of the implementation of genomic technology in the Australian dairy industry

A report for NUFFIELD AUSTRALIA FARMING SCHOLARS

By Paul Mumford

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Foreword

Coming from a farming family who had a strong affiliation with the land and its environment, and seeing agriculture as a social building block for the local community; farming was my only option! However, this did not become apparent until entering the work force where I began my career as a bank officer. After some seven years my passion for farming saw me leave the bank and realise my future. To me, it was the definition of what dairy farming in agriculture was all about, and it is these values that I believe make farmers unique!

Agriculture and the farming lifestyle were perceived as the environment conducive to an ideal lifestyle that both my wife and I were brought up in. It was an opportunity we felt should be offered to our children to allow them to share the experience and freedom of livelihood, with the strong morals and support that we were raised in.

My independent farming career started with leaving my bank officer role and moving to my grandmother's property, where our new farming and family life was to commence. It was soon realised that I had a natural ability to relate successfully with animals and manage a business and herd of cows on my own, as breeding cows was a skill that I portrayed even as a youngster. As time passed I was able to recognise the flaws and benefits of animals bred on the farm through previous generations, by myself and my forbearers, hence the passion for genetics, and as technology progresses into the new age of genomics, so too has my interest to keep abreast of new technology and ways that it can be implemented into the breeding program of the Australian dairy industry and my herd.

This new technology has the potential to give significant value to both the dairy industry and the service providers, in reducing the time for proving young sires offered to the dairy industry and more importantly, the dairy farmers by means of selecting superior sires to breed the next generation of dairy herds. This breakthrough will lead the dairy industry in quantum leaps forward by increasing the profitability of our farms and businesses as well as supplying greater levels of dairy foods to the growing world population, an ever increasing concern that is reflected on a global scale.

This report, sponsored by the Gardiner Foundation, will not only look at the potential benefits of genomic selection in dairy cows but also at some of the disadvantages associated with this new technology as these negatives could have a significant bearing and can greatly impact the dairy industry's future. Other impacts and conflicts of interest may have a long term effect on the success of implementing genomics and I will address these issues the dairy industry and policy makers will need to consider if it is to be successful.

It is my intention to present a usable document by dairy farmers of Australia to allow them to embrace this technology to the fullest and gain the maximum genetic potential available while revelling in the financial benefits that genomics is capable of delivering.

Acknowledgements

Firstly, a huge thank you to my family. To Lisa, my wife, who worked with strength and courage in some challenging times in my absence, and kept the family and business afloat. She embraced my passion to seek the answers to my questions with me, and my three children; Jessica, Chloe and Bryce who supported both Lisa and myself on this my Nuffield journey.

To Nuffield Australia for giving agricultural people here in Australia the ability to enhance their knowledge and open the doors of opportunity to advance themselves and the industry, forward.

Thank you to Jim Geltch, CEO Nuffield Australia and his team for the organisation and support they have shown throughout my Nuffield experience.

To my sponsors, The Gardiner Foundation for their continued support given to the scholarship program and the support they offered to my family in my absence. I trust we can continue our friendship long into the future.

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To the co-workers that help Lisa and I run the business while I travelled on my scholarship. Aaron Thomas, who had control of the general running of the farm, which ran particularly smoothly without a hitch of any major importance. Kate Dyer, Brian Hall, Ashley Thomas and Brendan Simmons who all filled in whenever and wherever they were needed, and their valuable contribution to the smooth operation of the business in my absence; a big thank you.

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To our Bank Manager - Scott Price, for encouraging me to apply for this scholarship and for supporting our business during my absence.

Finally, thank you to my wife Lisa for sub editing my report, and to Rose Walker for giving it a final professional edit.

Abbreviations

AB	Artificial Breeding
ABV	Australian Breeding Value
ADHIS	Australian Dairy Herd Improvement Scheme
ADF	Australian Dairy Farmers Limited
AI	Artificial Insemination
AJCA	American Jersey Cattle Association
APR	Australian Profit Ranking
ASI	Australian Selection Index
CDI	Centre for Dairy Information
CDN	Canadian Dairy Network
CEO	Chief Executive Officer
CRC	Cooperative Research Centre
CRI	Cooperative Resources International
DNA	Deoxyribonucleic acid
DPC	Data Processing Centres
GFC	Global Financial Crisis

GFP	Global Focus Program
GM	Genetically Modified
GMACE	Genomic Multiple Across Country Evaluation
IGE	International Genetic Evaluation
IP	Intellectual Property Rights
MACE	Multiple Across Country Evaluation
NLIS	National Livestock Identification Scheme
SNP	Snip – single nucleotide polymorphism
UK	United Kingdom
USA	United States of America
RNA	Ribonucleic acid

Definitions

Chromosomes: a rod shaped structure, usually found in pairs within a cell nucleus that carries genes to determine the sex and characteristics of an animal that has inherited traits from its parents.

Cloning: refers to a process used to create genetically identical copies of DNA fragments, cells or organisms.

DNA: a nucleic acid molecule in the form of a twisted double strand helix that is the major component of chromosomes and carries genetic information. DNA, which is found in all living organisms except some viruses, reproduces itself and is the means by which hereditary characteristics pass from one generation to the next.

GM: (genetically modified or genetically engineered) is a term associated to the direct manipulation of an organism's genes. Genetic engineering uses the techniques of molecular cloning or transformation to alter the structure and characteristics of genes.

Gene: the basic unit of transmitting characteristics from one generation to the next. It consists of a specific sequence of DNA or RNA that occupies a fixed position locus on a chromosome.

Genomic: the full complement of genetic information that an organism inherits from its parents, particularly apparent in the set of chromosomes and the genes that it carries.

Nucleotides: a component of DNA and RNA, consisting of a nucleotide linked to a phosphate group.

Genotype: the genetic makeup of an organism consisting of an entire complex of genes inherited from its parents. The genotype determines the hereditary potentials and limitations of an individual. Sexual reproduction guarantees every animal to have a unique genotype, except for multiple birth animals which come from the same egg; e.g. identical twins.

Protein: a large complex molecule made up of one or more chains of amino acids. Proteins perform a wide variety of functions within a cell.

RNA: a nucleic acid containing ribose found in living cells, essential for protein synthesis. RNA also acts as a replacement for DNA as the genetic material in some viruses.

Executive Summary

Background

The domestication of the dairy cow as we know it today can be traced back to over 1,000,000 years ago to the first recorded fossil finds of the ancient ancestral Aurochs. These animals lived in similar herds to their descendents, in wooded forests, swamps and grasslands. The species survived until the final animal died at a zoo in Poland in 1627, where its skeleton is located at the National Museum in Denmark.

The Aurochs was domesticated by pre-historic man some 10,000 years ago after the species diverged somewhere around 500,000 years ago, into two main species known today as Bos indicus and Bos taurus. It is the Bos taurus genotype that dairy cows of today have descended from. Since the commencement of domestication, cattle have been chosen for their functional traits allowing humans an outcome conducive to their needs. Today we have desirable traits in dairy cows that deliver high milk yields, protein and fat, as well as functional traits including conformation, temperament and milking speed, all of which have an effect when evaluating the efficiencies and profitability of a dairy operation.

Objectives

The aim of this report is to allow the general dairy industry to embrace the use of genomic technology with confidence and strive for a greater genetic advancement of their dairy operation, thus allowing the Australian industry to take advantage of these genetic gains when selecting criteria to enhance the performance in milk production, workability and functional traits, which will aid in the worlds' increasing appetite for dairy products and population growth.

In order to achieve this, a number of ways will be illustrated through the benefits of genomic technology within a breeding program of bulls, individual dairy farms and their stock, as well as highlighting the negatives that may arise from the introduction of this new technology. Issues in relation to policies and procedures will also be touched upon.

Results

In 1994 the genomic revolution started with the sequencing of an entire genome found in herefords, in the United States of America (USA). Scientists used SNP (pronounced snip) technology to evaluate traits expressed in an animal's genome and then compared it against contemporaries to assist in the calculation of breeding values.

Put simply, genomics is the ability to evaluate an animal's genome, comparing the genes against a database of predecessors allowing the breeding value of an animal's many different traits, to be determined. This tool will assist farmers using breeding values to achieve maximum gains in desirable traits like milk volume, protein yield and calving ease. The breeding values are then offered to the wider industry in the form of Artificial Breeding Values (ABV)'s, Australian Selection Index's (ASI)'s or Australian Profit Ranking's (APR)'s. These values are then ranked amongst themselves to enable dairy farmers to make informed breeding decisions to improve their dairy herds.

A major disadvantage looming in future generations of genomic selected animals is the effects of in-breeding. Farmers have the ability to select the very best in genetic material and advance their herds and/or balance sheets, which can lead to the narrowing of the gene pool within a particular breed. This in-breeding is capable of causing negative effects for those traits the dairy industry is seeking.

Recommendations

- A clear and precise data system for the transfer of production and trait information must be implemented into the Australian dairy industry in order to obtain the maximum leverage that genomics can deliver.

- All industry related organisations from semen retailers, government bodies, Data Processing Centres (DPC) and service providers to the dairy industry must emphasise to the farmer, the importance of herd recording either through encouragement of participation or an enforced requisite governed by industry bodies.

- Trading of bull genomic data across the world will give all countries the ability to add numbers and reliability to a database, offering the industry as a whole, clearer and more pronounced factual data.

- Genomics has the ability to take quantum leaps forward in genetic gains. It is of the utmost importance that the dairy industry maximise these genetic gains, embrace new technologies and farming systems confidently in order to reap the potential gains.

- The formation of a universal gene bank of animal genetic material for the possibility of any future issues arising from in-breeding, disease outbreaks or genetic impurities not yet foreseen. Any one of these examples has the ability to inflict huge implications on the dairy industry and cause a backward step. A gene bank will promote the correction of issues unforeseen and allow the industry a chance to move forward into the future.

- Genomics can and will be a powerful tool for dairy farmers around the world to use as a tool for improving their own herds' traits and ultimately advance the profitability of their farms however, genomics is still within its infancy and should be entered into like any new product or service, confidently but cautiously!

Introduction

Nuffield was something, I must admit, I stumbled into and it perhaps could be said that I didn't have a true understanding of the commitment and tasks Nuffield was going to ask of me, nor the effects it would have on my business. It first started in July 2008 when I decided that I would apply for the scholarship and as usual, I would leave this to the last stroke of the hour before emitting my application online by the due date. Surprisingly, not only did I make it through the stringent elimination process but I was actually successful in obtaining my Nuffield Scholarship.

The scholarship commenced with a meeting of all current scholars for 2008, from around the world, together in London, for one week to discuss topics and start the network process. This was ultimately organised in my opinion, to illustrate the forces affecting farming in the wider community, and how agriculture was planning to sustain the world's population growth into the future. This was achieved by introducing us to different forms of agriculture, politics and culture in and around Europe. The last remaining days were spent visiting the war fields of France, which highlighted the previous week's informative meetings, as one of the effects that agricultural policies can have on international trading partners is war!

The next leg of my journey was to gain a broader spectrum of agriculture from around the world, new technologies, political policies and cultures that influence farming within our own environment. This was for a 6 week period travelling in some 11 different countries with 9 other fellow scholars, gaining knowledge on many different and diverse aspects of farming, with a particular focus on techniques used to advance local businesses forward. Visiting the International Rice Research Institute and Ireland illustrated this with genetic work being done on cereals, enabling yields to be increased for economic reasons. Some of the benefits highlighted were quality standards in dietary requirements, increase crop yields for the selection of rice grains to decrease the speed of cooking times which has the ability to reduce carbon footprints and the impact it has on the environment.

The final part of the Scholarship entailed a 10 week study tour to broaden the knowledge for my study topic and how different parts of the world were tackling genomics, how they were evaluating DNA and how they were implementing this information into usable data and offering that data to the wider farmer base. This took me through nearly all of the major grass based dairy producing countries of the world including New Zealand (NZ), England, Ireland

and Canada. I was able to view their farming practises and learnt how they are handling the implementation of genomics into their countries, as well as experience and enjoy the hospitality and culture of these countries.

The History of the Bovine

The history of the genome of today's dairy cow can be traced back somewhere between 500,000 and 1,000,000 years ago the cattle ancestor 'Aurochs" (Bos primigenius) (or urus) digressed into a more familiar species that we know as the Ancestral Bos indicus, which includes animals such as the Zebu Cattle or humped cattle like the Brahman, and Bos taurus whose ancestors we recognise as the Jersey, Friesian/Holstein or Angus beef cattle.

The domestication of the dairy cow is estimated to have happened somewhere around 10,000 years ago from known fossil finds of the Bos primigenius (or urus). Over this time humans have been manipulating the traits of animals to suit their own purposes, whether it is for milk production, horse power or meat.

The Aurochs were believed to have lived like the modern cow of today in a mixed herd consisting of cows, calves and young bulls. The mature bulls had herds of their own with a few solitary alpha males being lone animals. During the breeding season they would join the female herds for courtship and control. Originally they occupied a distribution area that included the European Continent, Asia and North America however, the strain of today's animals can be traced back to the European sub-species hence the remaining species slowly becoming extinct. Hunting, by humans, for their meat and hides, natural nutrition and environmental impacts are believed to be the factors contributing to their extinction.

Research proves, from bones that have been found and old descriptions, that the aurochs appeared to inhabit swamps, river delta, bogs and a variety of swamp woods, feeding on grass like plants, herbs and the leaves of trees and shrubs. Mature bull skeletons show that this animal once stood around 2 meters tall at the shoulders, and is estimated to have weighed over 1.5 tonnes. The horn structure was an impressive 2 meters across the face of the animal's head, making him an imposing creature.

Picture 1: cave painting of aurochs in Lascaux, France
(Maas, Bos primigenius primigenius, 2008)

The last remaining aurochs died out as late as 1627 in Jaktorow, Poland after a long period of policy protection brought on by the royal family, even though attempts are being made to re-build the breed today. This first started in 1910 by brothers Lutz and Heinz Heck of Germany, who set out to re-birth the breed from those traits that the Aurochs was known to have. The two brothers chose different breeding strategies for each of their herds and within a short period of time they had succeeded in their objectives, with a strong resemblance to the original breed. The animals had been bred for specific traits known to exist in the original breed and are still found around the world in smaller numbers. Today they are commonly known as ‘Heck’ cattle. The Bos aurochs digressed into two different strains between 500,000 and 1,000,000 years ago and have descendents from the Aurochs genus that we know as Bos taurus and Bos indicus.

Picture 2: shows one of the domesticated animals descending from the Bos aurochs, being a Jersey cow which belongs to the Bos Taurus genus
(Gelbeado Park 104th, 2007)

The Evolution of Genomics

The genomic revolution started when researchers first sequenced the Hereford cattle genome in 1994 in the USA, and found that the bovines of today were made up of a mere 30 chromosomes, but possessed some three million nucleotides along their DNA strand.

It is important to note here that there is no GM in genomic. Genomics is purely the identification and evaluation of specific traits that farmers use to assist in their breeding objectives. There are no alterations of the gene in any way, shape or form.

DNA technology is moving so quickly in this technological age across all aspects of animal life and the bovine genome is no different.

The process used to extract DNA from an animals' tissue containing cell matter is usually done on a large scale, by plucking hair samples from the roots of the animal's skin or taking blood, saliva or meat samples.

The illustration in Diagram 1 shows the sequence that scientists use to evaluate a DNA strand of an organism which in this case is a bovine animal displaying 30 chromosomes within a cell. The number of chromosomes do not change within a species however, across other species they do i.e. humans have 46 chromosomes. The cells are in pairs creating an 'X' shape made up of deoxyribonucleic acid which are shown as the building blocks of a DNA strand. A closer look at these strands shows that it is made up of a sequence of letters all tied together e.g. the letters A, T, C and G in the diagram below. It is these letters, when sequenced in a particular order; contain instructions for making proteins and these proteins are the basis of life determining the phenotype of animals.

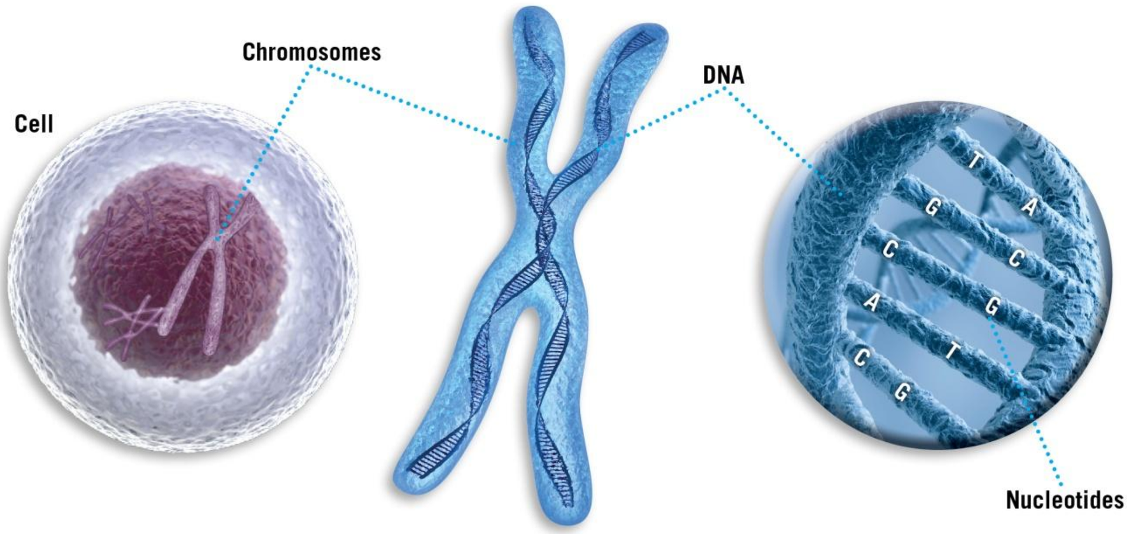


Diagram1. Illustration of how the nucleotides are captured within a cell
(Quinn)

DNA is moving so rapidly in this technological age that SNP technology is being updated as we speak. In the not so distant future SNP's of 700,000 units will be available for analysing DNA data. This is considered to be a quantum leap forward in scientific terms but what the outcome will be is still unclear. It is thought that this will clarify the current SNP information, giving a higher reliability of data. Like all technology it comes at a price and this new and improved SNP machine will come with a high cost attached to an individual animal's testing and at this current point in time, although technology will be available to use in detailed work on the cattle genotype, a 55,000 SNP gives enough information to successfully process ABV's and ultimately APR's within the dairy industry.

Gene markers are linked to observable traits like coat colour, as seen in the red factor gene of Holstein cattle, the double muscling of the Belgian Blue cattle or traits like the hair ridge in the Rhodesian and Thai ridgebacks. The markers are used by related the farming industries including farmers and AB retailers for economic importance to evaluate production, APR, survival or fertility.

SNP Technology

Many SNP's appear to have effects on complex traits, when they are seen in DNA. The way SNP technology works can be seen in Diagram 2 where there have been two animals tested and compared against each other. In the example the sequence of nucleotides across the gene are expressed almost identically, except for those in the 27th chromosome. This different make up of the gene is where scientist use SNP technology to calculate a genomic breeding value.

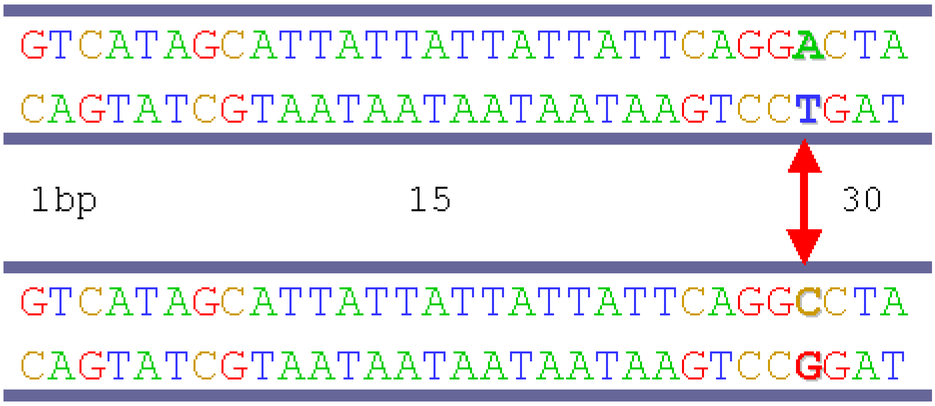


Diagram 2: Shows the location of a gene marker of interest which has been isolated by genomic technology.
(USDA)

To produce a usable form of ABVg through genomics, data needs to be collected from many different sources to enable industry bodies to formulate breeding values. Production and workability data is collected directly off farm via herd recording centres, where the collection of production traits, workability data, health, fertility, calving ease, and the parental average (PA) of the pedigree is required to complete the process. This data then proceeds through a very extensive process of complex mathematical equations to become the breeding values that farmers use for their breeding practises. This equation, to formulate a genomic breeding value, is the combination of true DNA genomic values and EBV's. The blending process is used to include animals in the pedigree of a genomic test that has value in its outcome. (Goddard & Hayes, 2009) (Nieuwhof, Beard, Konstantinov, Bowman, & Hayes, 2010)

To select elite bulls for widespread use within a breed, based on their DNA profile, rather than waiting for production and trait information on the performance of their progeny, will allow a span of some 3-4 years in genetic advancement. Currently, a bull considered to be worthy of a future investment to an AB Company, is screened for its estimated parental averages, and is then placed in a progeny test program where the animal is grown out, semen collected and then offered for sale. The in-milk daughters, which contain evidence of a bulls' proof is then processed by an evaluation centre like ADHIS, here in Australia. Overseas bull information through Interbull and classification data from the breed societies are also required to produce ABV information.

This procedure can take as long as seven years to reach however, the animal may not reach the relevant criteria set by ADHIS to issue a proven ABV, due to minimum standards not being obtained, before a reliable decision can be made in determining the testing bull's worthiness for commercial use.

An illustration of this can be seen in Diagram 3. This is where scientists from Genex in America have shown the basic benefits that are available to both service providers and farmers.

Name	Genomic LNM	Genomic LNM Reliability	LNM Difference
Cash	+$528	74%	-$110
Cassino	+$918	73%	+$280
Chester	+$573	73%	-$65

Diagram 3: Genomic outcomes from three sons of the same mother and father
(Cooperative Resources International)
(Wilson, 2009)

Here we have three full siblings with the same dam and sire, who is known as 'Ramos,' the same PA for their Lifetime Net Merit (LNM) and the same reliability. This would be expected in a comparison of these three bulls from the information available which has been concluded from a sight inspection and their PA. However, when these three sons were individually genomic tested and compared against the genome database, their LNM outcomes were markedly different.

From their PA, these three brothers, Cash, Cassino and Chester indicate a LNM of +$638 for each bull, while their genomic evaluation has given a complete different result. Cassino out performs his PA with a Genomic Life Net Merit (GLNM) of +$918, giving a financial gain of +$280. His brothers however, have performed in the reverse with a negative GLNM of -$110 and -$65 below their PA. This highlights the ability for farmers to select the very best genetics for the advancement of their herds and the ability for semen retailers to benefit by not having to carry those less productive bulls with negative genomic proofs, allowing them to be culled. Therefore proving more cost effective by not holding them for seven years, in order for their daughters to prove their real LNM as the current system dictates when proving a bull.

Even though this example comes from the USA, it does emphasise the role of genomics in a countries evaluation program and its ability to distinguish the most advanced progeny available.

Chapter 1.

International Uptake of Genomics

New Zealand

My first part of the individual study tour began in New Zealand and involved meeting with many business leaders, farm owners, co-operative delegates and various representatives within the dairy industry. Some of the businesses included Fonterra, ASB Banking lenders, commercial dairy farmers, stud breeders, farm consortiums – equity shares, share farmers, Livestock Improvement Corporation (LIC), Ambreed and Maori Land Management.

Since deregulation of the dairy industry New Zealand (NZ) is considered to be one of the most powerful forces in the international commodity of dairy foods. NZ is seen by its counterparts, as the market leader for efficiencies within the dairy industry. External forces on the countries dairy enterprise has been very menacing and is perceived as having one of the most intensive systems within all aspects of the dairy industry. The dairy industry holds a large market share of the NZ economy and this has inflicted many pressures on farming. Bankers here see the NZ Breeding Weight Index (BW) has a potential to lend money to the dairy industry and use this as a major tool to evaluate the economics of a farming system. However due to the Global Financial Crisis (GFC) with a dramatic reduction in farmers net equity, lenders in NZ have been forced to re-think their lending procedures and the use of the BW system in evaluating the dairy herds performance, purely because of data being shifted and the weight of their lending procedures dramatically changing.

The Breeding industry in NZ is mostly controlled by major market leaders being LIC with Ambreed next in line; both companies are located within a close proximity of Hamilton in the North Island.

NZ has been looking at genomics in the dairy industry since 1994 but the introduction of DNA evaluated sires has only been offered to their farmers since 2001. Here an error in the equation process of converting genomics to the NZ BW evaluating system forced NZ's LIC to recall their first genomically tested sires offered to NZ dairy farmers. This was seen as LIC having 'jumped the gun' due to a flaw in their DNA data process and prior a rigorous checking of calibration being overlooked. However, the potential for genomic selected

animals in NZ is expected to deliver a net worth of between $1.9 billion and $3.9 billion in extra profit to New Zealand dairy farmers over the next 20 years. It is predicted that a 70% gain will occur in the BW index and this is considered to be permanent and cumulative as generations pass on.
(Livestock Improvement Corporation)

A full list of DNA proven sires and conventional proven sires will take place during 2008 - 2010 and onwards. This will highlight bulls and their DNA breeding values indicated by a much wider genetic pool of animals. A 56,000 SNP system is used to collect this data.
(Livestock Improvement Corporation)

LIC is of the opinion they are able to offer better services and deliver quality pedigree bulls at a markedly cheaper cost, to the corporation and their farmers. This would cut the time it takes to market, sample, test and collect data which would enable better choices, services and returns favourable to their farmer base. Genomics will bring the ability for potential sires to be screened within a shorter time frame, therefore increasing the probability that exceptional new sires will be proven in a substantially shorter number of years and increase the rate of genetic merit and financial gain significantly.

Farmer's beliefs: This was a mixed response from the wider dairy fraternity, but the general consensus is genomics will be a valuable tool in their system however, due to the infancy of genomic revolution; an air of caution needs to be adhered to.

NZ plans to share their genomic data of previously tested bulls with Ireland in order to improve the reliability of information in both countries.

Ireland and United Kingdom

The United Kingdom (UK) and Ireland are at two very different points in the implementation of genomics into their industries however, the outcomes are expected to be very similar. The UK has had very little research done by scientists or industry bodies, where as the Irish have been investigating the process of genomics for quite some time and are at a point of offering usable data to their dairy industry. Discussions are currently underway between the two countries to adopt the Irish genomic evaluation process into the UK dairy industry.

The initial work in Ireland started with scientists at Moorepark Dairy Production Research Centre at Fermoy where in 2009 GEBV's had been assessed using a 50,000 SNP chip. Similar extensive trials have been conducted around the world to re-affirm similar findings in relation to the benefits of genomic technology. Here in Ireland genomics has evidential correlations that their existing breeding evaluation process of daughters confirm a bull's proof.

The Irish genomic process of introduction has been perhaps the cleanest, non biased system within the world. Data collecting and implementation of the breeding evaluation system and the genomic evaluation process is run completely independent. At this stage there is no independent organisation within the system that receives any monetary gain or beneficial advancement in the market.

Like most countries, the uptake of genomic evaluated bulls on offer within the dairy population has been very pleasing in Ireland. Most farmers are taking the cautious road where they are sensibly choosing a portion of genomic selected bulls and conventionally selected sires. This percentage seems to be around the 30% - 50% mark for genomically tested sires.

(Berry, 2010) (Kearney, Cromie, & Berry) (Berry & Kearney, Genomic Selection Procedures for Ireland (Version 1.1), 2009)

Canada & America

North America is perhaps leading the forefront of the dairy industry in the bovine genomic era however, is considered to be one of the last to introduce the new technology. The reasons for their leap into the forefront is mostly put down to the sheer size of their national herd base, allowing scientists the ability to create a large database of genomic tested sires that have been proven within a very short period of time, as well as having government support for each countries agricultural fields like, the American Agricultural Policy in the USA or government support of the milk quota system in Canada. This could be basically put down to the number of animals in their data set of breeding calculations, the larger the data set, to compare genomic evaluation, the higher the reliability of data.

In the USA a new state of the art SNP Chip has been created by scientists in Missouri, Nebraska and Maryland, to identify DNA markers for economically important traits in livestock which include milk production, disease susceptibility, reproduction and type traits.

The ability to identify genotypes of more than 56,000 single nucleotides evenly distributed over the bovines 30 chromosomes, is detailed within this SNP Chip. However, at this stage, around 20% of these SNP's are considered unusable, leaving close to 40,000 SNP's to be utilised in both the Jersey and Holstein genome to evaluate breeding values.

Reliabilities of 60 – 70% are being found after the genomic testing of a potential young sire which is a marked difference to the normal reliability of 30-40% from using a PA as you will see later in this report. These improvements are estimated to be far better than that of Australia, due to the larger selection of bulls available in the American and Canadian systems.

New technology is advancing so rapidly in the Americas that SNP chips of 700,000 markers will soon be available for commercial use, if not already in use, across the data evaluation process of the cattle genome.

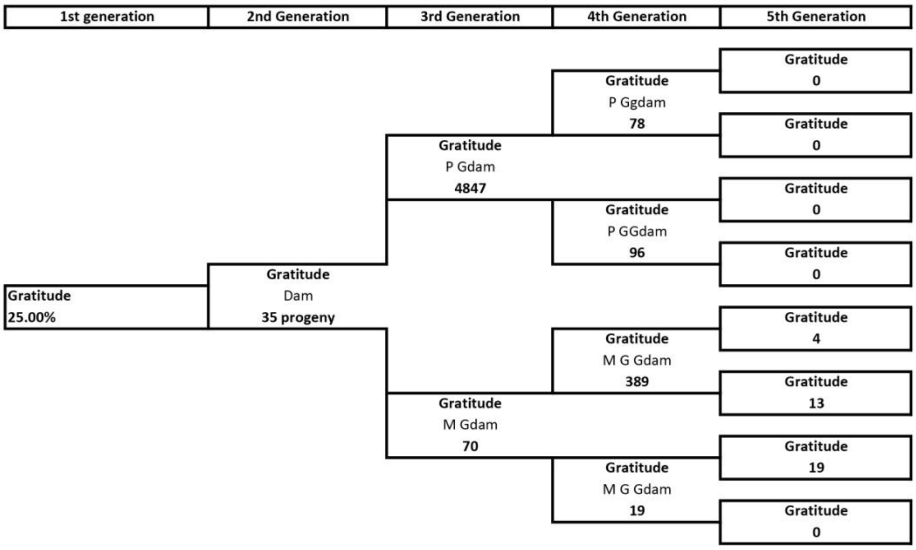
Chapter 2

Effects of New Technology

An interesting aspect that implicates the effects genomics can have on any species transpired when the discovery of a Holstein gene in a jersey cow "Oomsdale Gordo Goldie Gratitude 111224922" (Gratitude) was discovered in her genome. This gene made her and her progeny impure and unusable for the purposes of registered breeders. The shockwaves of this finding were immense as she was considered to be a most influential dam of the Jersey breed in her ability to pass down superior traits to her progeny.

Progeny of Gratitude in Registered Jersey Population as of 1/31/2010

Blocks containing the name "Gratitude" indicate where she appears in pedigrees.



	2nd Generation	3rd Generation	4th Generation	5th Generation
Total Progeny (5,551)	35	4917	563	36
Generational progeny name	Progeny	Grand Progeny	Great Grand Progeny	Great Great Grand Progeny
Dam count	Dam	2nd Dam	3rd Dam	4th Dam
Percent non-Jersey genes	12.500%	6.250%	3.125%	1.563%
Fraction non-Jersey genes	1/8	1/16	1/32	1/64

Diagram 4: The Impact of "Gratitude's" bloodlines on the Jersey breed

(The American Jersey Cattle Association, 2010)

The discovery came about with the use of SNP technology being implemented into the American Jersey Cattle Association's protocols for identification of parental verification in 2009. "Gratitude," originally DNA tested in 2002, along with her dam and maternal grand dam, with technology available at the time of testing, found no conflicts with regards to the parentage however, the jersey sire in question was unable to be tested as he has deceased. Although “Gratitude” is now deceased and is unable to be genomically tested, researchers were able to use genomic information from her progeny, to determine 22.3% of the Holstein gene was evident and this is more than likely to be sourced from a red-carrier Holstein bull.

This evidence supports the theory that “Gratitude’s” mother was not actually purebred progeny which the owner/breeder thought she was, and that her registration within the breed society files contains information that derived from a direct descendent of a red-carrier Holstein bull, thus leading to the de-registration of her and subsequent progeny.

Diagram 4. highlights that some 5,551 progeny from this animal are registered with the AJCA as at 31st of January 2010. This figure does not include the number of animals that are yet to be registered, animals still to be born, nor animals that are being used by commercial farmers, with no membership to any breed society. This data is only available for use by the American population, therefore the true impact around the world will be quite significant and the effects will not be realised for some time yet.

This perceived elite cow within the jersey breed, has been responsible for a major amendment to procedures in identifying potential cows, bulls and pedigree registrations both in America, Australia and right around the world in all breed societies.

AJCA, responsible for the jersey breed rules and regulations is also the controlling body for all pedigree registrations and has taken steps for allowing animals descending from this cow to retain their current registrations but be demoted to a stage class animal. Basically, the progeny from this line of genetics will not be considered as pure nor will their descendents. However, as the generations pass down from “Gratitude” the percentage of non-Jersey genes will gradually diminish and after the 4th generation, there will only be 3.125% or less Holstein genes present and only 1.563% of the Holstein gene will remain in the 5th generation animal.

A rippling effect has been caused by this discovery, not only across the Jersey breed but major implications have arisen across all livestock breed societies, highlighting the effects of genomic testing and its capability to state influential facts about DNA in animals.

Breeding societies in countries around the world have been forced to amend their rules and regulations, due to the implementation of genomic DNA and its effects. For example, the Danish breed society has slaughtered all sons born from "Gratitude's" immediate progeny and all daughters have had their registration downgraded to reflect the appropriate stage of impurity on their pedigrees.

New Zealand and Australia have also de-registered all sons and their progeny available for registration by AB companies as they are considered to be outside the minimum requirements for registration of animals within the breed societies.

The problems occurring from the vast use of a descendent from this bloodline is snowballing through the breeding herds of dairy farmers in Australia. "Gratitude's" favourite son, "BOSGannon" used quite extensively over the previous 2 lactations has caused the Australian Jersey Breeding Society (AJBS) to down grade approximately 150 pedigrees to a Stage 3 status, effectively marring the animals' bloodline and influencing breeders to maintain a high pedigree. This also has a negative effect on the sale of potential bulls to the AI industry and impacts the sale of females for pedigree purposes. This figure does not include animals currently carrying "BosGannon" daughters and expected to be born this spring. We can estimate the same number of progeny could be offered for registration here in Australia and perhaps even universally.

Progeny in main stream commercial dairy herds not registering their cattle with breeding societies have been excluded in these statistics and there could be 3 - 4 times the number of animals in these herds. It should also be noted that "BosGannon" is in no way a 'freak,' it merely retains a recessive red Holstein gene reducing the purity of a bloodline within the Jersey breed. The animal is no different to when it was born and still passes on all of the traits described within the breeding value and it is still worthy of consideration to farmers that do not hold 'pure bloodline' status in their herd and across many breeds. When assessing a bulls pedigree, ABV or ASI data, it is assumed that ADHIS will implement an additional column, indicating whether an animal has been genomically tested. This will be represented by the letter 'g' at the end of data relating to ABV, APR or ASI.

Chapter 3

The Role of Interbull

Interbull has been put in place as a sub-committee for the International Committee for Animal Recording, with 42 members representing worldwide nations, its role is to offer a global network to supply genetic information for the improvement of the global dairy industry. This entity manages the transferral of statistical information on bulls and cows to usable data required by participating countries evaluation programs and co-ordinates international communications and research.

This organisation was set up in 1983 for the use of cattle breeders and semen retailers to make accurate comparisons between animals from many different countries. The majority of information detailed the performance of in-milk daughters across a variety of different countries. This proved difficult due to the different system each country had in place when evaluating an animal's production and type traits. So a Multiple Across Country Evaluation (MACE) program was set in place to cater for the different evaluation processes and incorporated issues relating to breeding objectives, environmental effects on animals, management styles and differences in the level of genetics each countries animals possessed. The organisation had to allow for these different challenges in their calculations, which led to the first international evaluations taking place in 1994.

Today these services are still being provided and improved for the services to members of Interbull however, additional services have been introduced to the Interbull portfolio currently available and the International Genetic Evaluation (IGE) service is one of these. This program evaluates sires of six different breeds and traits which include: milk production, conformation, longevity, udder health, calving and female fertility using the MACE program to re-calculate and disperse animal data back to participating countries. Because of this process Interbull are believed to hold the largest genealogic database on any domestic species.

This development in genomic technology has however put Interbull at the crossroads; does it take a commanding role in the evolution of genomic technology? Or does it keep the current breeding methods for international comparison as their focus? Interbull has decided to develop a strategies plan and established the Genomic Multiple Across Country Evaluation

(GMACE) to cater for implications that genomics has on the transfer of data between countries. Interbull claims to have created the GMACE program and implement pilot runs for the validation of protein yields in August 2010 to locate and amend any problems that arise. They are expecting to have other traits validated by their program at the end of December 2010. This will then be offered for wide spread semen use and young sires.

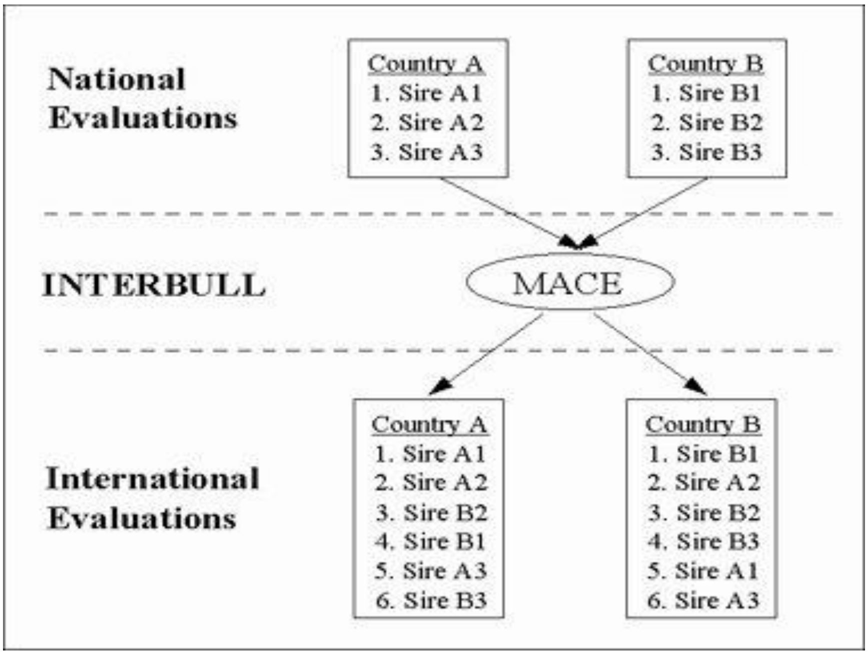


Diagram 5: Interbull evaluation conversions through the MACE program
(Dr Forabosco & Palucci, 2010)

The demonstration as outlined in Diagram 5. shows how the International Genetic Evaluation process transpires for calculating two separate countries ranking their animals under the national evaluation program. Interbull then calibrate and rank this data according to their MACE conversion program and then disperse the information back to participating countries. It must be noted this new ranking will vary in each country, due to having a different set of ideals for the evaluation of animal data within their own environment. Examples of these differences are climate, management and environmental impacts like housing of cows against free range animals. The GMACE program operates within similar guidelines and will offer similar information for genomic animals.
(Interbull Centre, 2009)

Chapter 4

The Australian Way

The Australian dairy industry has seen vast genetic improvements over the last 70 years with the introduction of Artificial Insemination (AI), herd testing, semen processing, sire proofing, introduction of breeding values for traits and now the evolution of genomic technology. From the early years of introducing insemination to Australia, the industry has seen a vast changing landscape.
(Dairy Australia, 2009) (Rowley & Chester, 1980) (Stubbs, 1996)

These advancements in the industry have had a huge impact on the dairy enterprise, their farming families, community, society and the governments' GDP.

Genomics is yet another tool for dairy farmers to use as a guide in assisting the process of advancing the dairy industry forward.

Currently, when a bull in Australia graduates to a proven status its ABV information contains ancestral data as well as daughter performance information. This ABV can then be used to formulate other indexes that are crucial to the Australian dairy industry like the APR and ASI listings issued by ADHIS.

Within this system of proving a bull, a minimum of 7 years is allowed per animal, from the process of maturing it to a point where it is able to produce viable and saleable semen. Widespread use of the bull does not happen until it reaches the age of five years.

The science sounds great in theory, but will it work or make sense in practise? Here in Australia, scientists have used a system to validate their data utilising historical bull data and their proofs from a daughter's production and type traits to validate the equations in assessing a genomic breeding value.

The Role of ADHIS

Data in Australia is managed by the Australian Dairy Herd Improvement Scheme (ADHIS) which is a not for profit organisation and is a wholly owned subsidiary of the Australian Dairy

Farmers Limited. Its formation developed from the recommendations of the standing committee on agriculture following lobbying from key dairy farmers and industry representatives for a national genetic evaluation scheme.

ADHIS is Australia's independent genetic evaluator and oversees the transfer of production, type and trait data supplied from the national dairy herd. Their first usable data was offered to the Australian dairy industry in 1983 with the first ABV's for production traits released to the dairy industry, type traits followed in 1986 and workabilities in 1989. Since the 1980's its primary role has been to calculate and communicate breeding values. Over this time they have enhanced their procedures in regards to breeding values and now offer over 40 traits to the industry. They manage the national database of herd records for both male and female data.

1997 ADHIS joined Interbull to address concerns on how to manage overseas bulls offered to Australian dairy farmers.
2007 – Gene marker tests used to pre select progeny test teams by AI companies
2008 – PT teams offered to dairy farmers with genomically selected traits
2010 – April. The release of ABV's into the Australian dairy industry, as well as an internal test run of the ABV (g).
Aug 2010 – New evaluation of the ABV system including genomic evaluation in the data (Nieuwhof, Beard, Konstantinov, Bowman, & Hayes, 2010)

Part owner of the genomic technology process with GA, DA and CRC for innovative Dairy Products.

As the genomic selection is still within the infinite stage of existence, the use of genomic bulls with selected traits did not commence until 2008 and is not likely to have valid data until 2011 when ADHIS expect to publish these bulls under the heading of ABV(g) which stands for a genomic bull used to calculate its breeding value. This is done by assessing its genomic BV along with its pedigree / performance BV.

Non proven sires can only graduate to 'proven' status when the production data reaches a reliability of 63% and has a minimum number of milking daughters within 15 different herds. If the figures fall below these parameters then the bull is given an ABV(i) which gives the animal an estimated breeding value and indicates that it will not officially graduate until more daughters come into milk. This enables a sire to be proved accordingly by setting a minimum requirement regulated by ADHIS for a publishable proof.

Current data flow for genomic testing in Australia is:
Collect DNA material from animal, cow or bull
Verify animal detail data
Lodgement of DNA sample to lab
DNA analysis return to ADHIS
Deliver results to lodging applicant or advised recipient

This process will take an estimate of 11 -20 weeks to complete.

Owning the Technology

Genomic selection fees for bulls are estimated to cost around $450 for 30 samples or less and $350 thereafter with a flat $350 per sample for cows. These are to be processed through Gene Express Pty Ltd (Gene Express).

This service allows all players within the dairy industry, to access gene technology and includes farmers conducting their own testing of elite cows or DNA testing their own herd bulls to use for the farm's requirements. However, the major up take in the short term will come from commercial AB companies seeking elite cow families and sires for future use within the industry.

As this service is still within its infancy in Australia, it has been limited to the Holstein breed however, there is currently work being completed for other breeds such as the jersey breed for genomic evaluations. This has been funded under the Futures CRC project.

Another incentive, to encourage the use of this technology, is the inclusion of large numbers of females to be tested in order to add reliability to a sire's information. There is an estimate of four cows and their genome will give scientists useful bull data. This has been approved by funding under the Dairy Futures Co-Operative Research Centre (CRC) known as 'The 10,000 Cow Genomes Project' and will commence this winter with an expected completion date of September 2011.

This is where a total number of 10,000 animals will be selectively tested for DNA analysis from the whole Australian dairy herd. The major criteria for this selection is animals with excellent herd record data which will enable scientists and ADHIS to derive more reliable ABV(g)'s for selected animals, while improving data on traits that have low reliabilities even for proven sires, the two major traits being fertility and survival. This will allow both ADHIS and scientists to maintain and evaluate data for future reference with regards to comparisons of an animal's genome.

Presently, no formal protocols have been directed from the governing body ADHIS however, the assumption of strict protocols will have to be adhered to. Some of which the details of traceability require would be such things as date, sample number, farm cattle identification number, national herd identification number, NLIS number and farm national herd ID number, sex etc... This information would be required for the correct completion of NA genotyping allowing a diverse dispersal of data through all facets of the industry, for example; breed societies, Herd Improvement Organisation (HIO), farmers and AB companies.

There should be a strictly confidential requirement for the traceability of DNA samples for the reason that ADHIS can control the data transfer between farmers/AB companies and privately owned labs, which have a financial interest within the AB industry. There needs to be some mechanism to have this traceability.

Issues Facing the Australian Dairy Industry

The Australian dairy industry has been facing major challenges over the years with drought, GFC, milk pricing, government regulations, land prices etc.... The AB industry has also felt the effects imposed on the farming community and the have managed to deal with the challenge of this volatile market by adapting to their new surroundings. Some retailers and service providers in the industry have seen amalgamation as an important measure to assist in coping with their changing environment. Some have sold out to interested parties, both from here and overseas, while others have chosen to consolidate and restructure their business to suit these demands.

The involvement of a privately run business in any enterprise, whether owned by shareholders, partnership or a co-operative based business having a financial interest in the process of collecting or handling, will be seen amongst the wider dairy community from the farm-gate level or further along the chain, as an ability to corrupt data regarding genomics. The role of collecting the data should be handled by an individual body (whether governmental, industry based or whole industry owned) as this is the only way to keep data pure for the benefit of the farmer and for the goals that are trying to be achieved by these industry bodies.

If the industry does not have a clean data source then it will fragment the dairy industry and allow the semen retailers, whether gnomically tested or not and other services relating to the AB industry, to look elsewhere for the same information. This will be detrimental to the Australian data as it will reduce the reliability of an uptake in animals offered within the Australian system.

Currently, there are AB related companies seeking to use and sell bulls from Australia which have been genomically tested outside Australian guidelines. There are two main reasons for breeding companies to be concerned about this. The first is the slow pace in which this technology has been able to be put in place and commercial companies are able to use this system. In Australia it has taken some 15 years since the first steps were made to offer services for this technology, commercially. The second is that a commercial competitor, to an AB company, has a vested interest in the technology and/or the process and the perception of corrupted data being transferred with an unfair advantage pointing towards the business which in this scenario is (GA).

One way to counteract this problem may be for data service collectors to impose a mandatory genomic test under Australian guidelines and evaluations, to add reliability to their data set however, this will ultimately come at a cost eventually being passed onto the farmer.

A centralised data collection centre is feasible and would allow a central industry body having no vested interest in commercial activity of the data to evaluate, record and control the data exchange, conversion etc. This could be a single data collection point allowing many different facets of the industry to add or subtract relevant information. An example of this could be similar to that of the Centre for Dairy Information (CDI) set up in the UK. The goal there is to develop a single, comprehensive and integrated data base for the dairy industry and allow the storage and analysis of usable data to transfer the knowledge into a more manageable and user friendly system.

In the UK goods and services are offered to the farmer relating to: data and statistical information like production information, type trends and workabilities. Health and Welfare which incorporates animal health and their well being are included in the National Animal Disease Information Services. Management tools for the farmer like registrations of animals to the national data base and breed societies, bull selection tools or industry related issues, can be accessed by farmers. It also has the ability for users to access the web site from industry bodies like AB companies, veterinary practises, government departments and breed societies to name a few, who can obtain limited broad spectrum information related to all forms of the dairy industry. The dairy farmer can also access personal farm information as well as the broader industry data. The single base website organisation provides real benefit to farmers in giving real time data and eliminating the time consuming double handling of paper work.

This site originated for encouraging farmers to think smarter and look for alternatives to issues that face their businesses due to the widening demands from consumers to enquire about the quality of products being utilised, time management issues within their businesses and the uptake of technology from farmers within the UK.

AB companies require the collection of relevant DNA data under the correct protocols to allow the smooth transition of information from farm level to the lab and the return to ADHIS.

The implications that will follow from the discovery of Holstein genes in the case of Oomsdale Gordo Goldie Gratitude have highlighted both strengths and weaknesses for the implementation of genomics, not only in the cattle genome, but for all breeds of animals and plants. It shows that we have the technology to isolate particular genes in any living organism, enabling information to be used for future enhancement of living matter however, it can also identify impurities within the systems currently in place for the evaluation of data, prior to the arrival of genomic technology.

Recommendations

Clear and Precise Data Transfer

One of the key findings in any statistics gathered can be summed up as 'the information offered is only as good as the data collected.' A clear and precise data system must be incorporated into the Australian dairy industry in order to obtain the maximum leverage that genomics can deliver.

It is imperative that any data collected from herd recording figures, workability data or confirmation evaluation, needs to follow a clear and definite path to the final users in order for service providers to evaluate in an appropriate and prompt manner thus delivering accurate and valuable information to the farming industry to allow farmers to make more informed decisions to drive their business into the future. This could develop from the formation of an independent entity responsible for administering data collection, transferring, evaluation and the dispersal of data which enables farmers to access a one stop real time web site that provides up-to-date information and eliminates double handling of paper entries and confusion of data errors from the dairy farm.

Increasing Participation in Herd Recording

Traditionally the involvement of farmers in herd recording in Australia has been very disappointing as cow numbers have decreased significantly over time. The dairy industry as a whole would benefit far greater if they would embrace this technology to its fullest as it is vital for the clarity and reliability of information offered by industry bodies like ADHIS and in particular for the accuracy of genomic data.

Industry organisations from semen retailers, government bodies, DPC and service providers to the dairy industry must emphasise to the farmer the importance of herd recording either through encouragement of participation or an enforced requisite governed by industry bodies.

Trading of Overseas Genomic Data to Improve Bull Reliability

Trading of animal genomics across the world will give all countries the ability to add bulls to their database this, in turn will allow for improvements of reliabilities in a particular animal's traits, giving clearer and more pronounced information to the dairy farmer.

Genetic Gains

Genomics has the ability to take quantum leaps forward in genetic gains, e.g. a 50% increase in milk production, directly impacting dairy farmer's right around the world however, the disadvantage of these gains may have an adverse effect on management of the dairy farm if there is an inability to cater for this improvement. It is of the utmost importance that the dairy industry, to maximise these genetic gains, embrace new technologies and farming techniques to handle these new systems.

This may add to the many reasons farmers are looking at changing to a more intensive system being implemented here in Australia and moving away from the more traditional low stocking rate pasture based feed system. Like urban land pressure, property values and environmental issues facing the future of dairy farming.

Formation of Gene Bank to Protect the Loss of Animal Genetics

A major effect that genomic selection will have on any animal; wether it is dairy cows, pigs or horses is the demise of the genetic pool in selecting animals with the greatest benefit. Genomics can have a negative effect on the gene pool if farmers continue to use limited bloodlines for the advancement of the breed.

The formation of a universal gene bank of animal data would overcome any possible issues arising from in-breeding, disease out-breaks or genetic impurities not yet foreseen and would allow the industry to back step and correct the issues that were unforeseen.

The Wholly Grail for the Dairy Industry

Genomics can and will be a powerful tool that dairy farmers right around the world can use to improve their own herds and ultimately improve the profitability of their farms however, genomics is still within its infancy although favourable outcomes are being experienced right around the world. This should be entered into like any new product or service; with confidence but caution!

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Plain English Compendium Summary

Project Title:	Genomics in Australia
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Objectives	The aim for this report is to allow the general dairy industry to embrace the use of genomic technology with confidence, allowing for a greater genetic advancement to cater for the worlds' growing appetite for dairy products and its increasing population. This will encourage Australian dairy farmers to embrace the technology and assist them in gaining the financial benefits that are associated with genomics for their farm businesses. Achieving this can be done in a number of ways, by illustrating the benefits of genomic technology in an individual dairy farms' breeding program, as well as highlighting the negatives that may arise.
Background	New genomic technology being released in Australia has great potential to enhance the dairy industry however, it has been one of the last countries to offer this technology. This has led to an overseas study throughout New Zealand, Ireland, Canada, Europe and the USA, to compare and understand the implications and relay this back to the Australian dairy industry.
Research	In 1994 the genotype revolution started with the sequencing of a herefords entire genome in the USA. Scientists use SNP (snip) technology to evaluate an animal's genome and compare it against its contemporaries to assist in the calculation of breeding values in the form of ABV's, ASI's and APR's. Genomic selection is the relationship between SNP markers and those important functional genes of a dairy cow, like milk yield, workability traits or calving ease. It can define an animal's genome over many different traits and compares these genes against a genetic database that dairy farmers use in their breeding decision; e.g. milk volume or fertility.
Outcomes	This technology has the ability to identify the most profitable animal available for farmers use as well as delivering it in a shorter and more economically time frame. By identifying bulls through genomics, there will no longer be the need to qualify for the progeny test system allowing semen retailers to save expenses associated with pedigrees unable to graduate. Additionally genomics will allow clarity of an animal's bloodline for registered breeders..
Implications	Trading of animal genomics across the world will give all countries the ability to add bulls to their database, thus improving the reliabilities of each animal's trait. Offering the dairy industry, a clearer and more pronounced factual data. Genomics has the ability to take quantum leaps forward in genetic gains, therefore it is of the utmost importance that the dairy industry maximise these genetic gains, embrace new technologies and farming systems to cater for these potential gains. The formation of a universal gene bank of animal genetic material for any future possible issues arising from inbreeding, disease out breaks or genetic impurities not yet fore seen, allowing the industry to take a backward step and correct any issues that were un foreseen, giving them the ability to correct any problems arising. Genomics can and will be a powerful tool that dairy farmers right around the world can use to improve their herds genetics potential as well improving the profitability of their farms, however genomics is still within its infancy and; should be entered into like any new product or service; with confidence but caution!
Publications	Current Genomic evaluations and equations can be obtained through ADHIS's website at www.adhis.com.au