An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine

Research Stimulus Fund

Final Report

'Genetics of cost production traits – GenCost'

DAFM Project Reference No: 11/S/133

Start date: 01/06/2017

End Date: 30/09/2018

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Collaborating Research Institutions and Researchers:
Irish Cattle Breeding Federation - Drs. Ross Evans, Andrew Cromie, Thierry Pabiou, Francis Kearney
Dublin City University - Prof. Harry Esmonde
University College Dublin - Prof. Tommy Boland

Please place *one* "x" below in the appropriate area on the research continuum where you feel this project fits

Basic/Fundamental → Applied → Pre Commercial

1	2	3	4	5	6	7X

Please specify priority area(s) of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report;

Priority Area (s)	Sustainable Food Production and Processing

Key words: *genetics; sheep; cattle; breeding programmes*

1. Rationale for Undertaking the Research

Rational: World human population is expected to grow to 9.1 billion people by 2050 and therefore food production must concomitantly grow by 70%. Although increasing genetic gain in output traits might seem most sensible, reducing the (resource) cost of production can increase output per unit area and also reduce environmental footprint. The feasibility of breeding for any given trait is dependent, amongst other things, by the availability of data, either on the trait itself or a genetically correlated trait. Ideally the data should be measurable early in life, preferably across genders, and be available at a low marginal cost. Output traits in most species are generally highly heritable and routinely measured; therefore the focus of this study was on: a) lowly heritable traits, and b) trait that are routinely difficulty to acquire data on.

Relevance: The statistical models and pipelines developed as part of this project where undertaken in conjunction with the Irish Cattle Breeding Federation and Sheep Ireland using the same programming languages and statistical software thereby ensuring ease of transition to implementation. All data generated immediately entered the national database. Irish farmers benefit from the results of this project through more accurate genetic evaluations for a larger suite of traits. This will result in greater profit in the longer term

Objective: To develop, exploit and disseminate state of the art tools to genetically improve cost-of-production traits in the dairy, beef and sheep sectors.

2. Research Approach

A two pronged research approach was undertaken in this study:

1. Where data was already available on certain phenotypes, such as novel dairy fertility traits and sheep health data, the relevant data was extracted from the ICBF and Sheep Ireland databases. Phenotypic and genetic analyses was subsequently undertaken to quantify the phenotypic and genetic variation in the traits. In addition genetic co-variances were estimated between the fertility and health data and the routinely recorded traits (i.e. growth rates, milk yield) to assess the potential of including the novel traits in the genetic evaluations.
2. Where data was currently unavailable phenotyping strategies were investigated, this included a review of the literature to assess the potential of new technologies to generate phenotypic data on a routine basis for management and breeding decisions. Technologies investigated included infrared thermography and pressure pads.

Irrespective of the research approach undertaken a strong focus was placed on the dissemination of all results to the relevant stake holders. In addition all data generated as part of this project, phenotypes and genetic data entered the ICBF and

Sheep Ireland databases to ensure exploitation of the results in the national sheep, beef and dairy breeding programmes.

3. Research Achievements/Results

Fertility traits

New and novel detailed fertility traits for beef and dairy cattle were identified following consultation with reproduction researchers and personal with expertise in the field. The phenotypes generated from the ultrasound examinations included: resumed ovarian cyclicity, cystic structures on the ovaries, early ovulation, uterine score and embryonic/foetal death. The contribution of both the additive and non-additive genetic components, as well as the permanent environmental component, to phenotypic variation in the reproductive traits in nulliparous seasonal-calving dairy females was also investigated.

New female fertility traits in sheep were defined following discussions with national and international experts and all the pertinent fertility traits were generated using data from the existing Sheep Ireland database. In addition male fertility was also investigated; data on male fertility was available from two main sources the Sheep Ireland database and the Teagasc BETTER farm database. A detailed report on the use of male fertility traits for sheep was completed.

Health traits

Health traits in cattle (bovine respiratory disease) and sheep (faecal egg counts, dag scores and foot lesion scores) were available from the national databases, therefore genetic analyses was undertaken. Results showed that ample genetic variation existed for all the health traits investigated and genetic selection for animals with superior health is achievable.

The ability of new technologies to quantify the health status of cattle and sheep was assessed. Three experiments were investigated: i) the repeatability of infrared thermography in an agricultural environment, ii) the relationship between udder skin temperature (measured by infrared thermography) and the quarter somatic cell count of dairy cows, and iii) the ability of infrared thermography to detect lameness in sheep. Approximately 8000 thermal images were manually captured in an agricultural setting, these data were analysed using a variety statistical methods. Results from this research will aid in the application of infrared thermography on farm, especially as a lameness detection tool for sheep.

Feed intake

Approximately 500 individual animal feed intake measurements have been generated on sheep and phenotypic and genetic analysis of these data has been undertaken. The impact of alternative definitions of feed efficiency in dairy cows was investigated. Exploitable genetic variation was demonstrated to exist for the range of alternative dairy efficiency traits, and the magnitude of this variation was sufficiently large to justify consideration of the feed efficiency complex in future dairy breeding goals. Variance components, however, differed across lactation when estimated using random

regression models. The impact of including the alternative efficiency traits on the EBI was also investigated. The EBI is currently selecting for higher residual energy intake (REI) cows but this could be reversed if REI was included in the EBI with the appropriate economic weight.

Milk production in suckling animals

A number of alternative methods were investigated for the calculation of milk production in suckling animals. This included both a phenotypic and genetic analysis across a number of growth functions including: von Bertalanffy, Gompertz and Richards models as well as random regression models (orthogonal and legrend polynomials). Results showed that the Gompertz model provided the greatest accuracy for further prediction of live weight records; this information is useful for the development of a phenotypic decision support tool for sheep and beef. Random regression models were utilised to estimate EBVs for milk production for individual animal from birth to weaning on beef and sheep animals.

Strategic Roadmap

A strategic roadmap for genetic research was generated using data collated as part of this study, including phenotypic and genetic variances for fertility, health and feed intake traits across sheep, beef and dairy. Selection index methodology was used to investigate the genetic gain achievable (both in production and monetary terms) from included these cost of production traits in the national breed objectives for beef, sheep and dairy.

Dissemination

A total of 20 peer review publications have been published as part of this study. Results from this project have also been presented to industry on numerous occasions this includes: national opendays (sheep and dairy opendays), international conference (EAAP conference), and at national (industry meetings and in-service training) and international seminars (British Texel Society and UK feed efficiency conference).

4. Impact of the Research

The overall impact of this research was the development of more accurate genetic evaluations for beef, dairy and sheep. The data and pipelines (e.g., data editing, statistical models) generated as part of this project has enabled the immediate exploitation of the results in national cattle and sheep genetic evaluations by the ICBF and Sheep Ireland, respectively. New genetic evaluations for fertility and health traits have been implemented as part of this research. In addition the knowledge generated on the genetics of feed intake and milk production on suckling animal will be introduced into the breeding programmes in the future. Ultimately this research will help to reduce fluctuations in animal genetic proofs, which is a characteristic of genetic evaluations that Irish stakeholders are demanding. A strategic roadmap was also developed to help prioritise future research to ensure genetic gain is maximised. Results have also been published in

high impact scientific journals as well as in the popular press and at (inter)national conferences, which will allow industry and other researchers to exploit the knowledge gained from this project.

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

Linkages with the research collaborators within this project, such as ICBF, Sheep Ireland and UCD, have been strengthened and have resulted in further collaboration on more recent funded projects. In addition new international collaborative links have been formed as a result of this research and has led to the inclusion of Teagasc in European funded projects on cost of production traits (ERA-NET project on ewe longevity and Horizon 2020 project on health traits).

(ii) Outcomes where new products, technologies and processes were developed and/or adopted

The benefits and drawbacks of the use of alternative technologies (i.e. infrared tomography and pressure pads) were identified that could be potentially used by companies to: 1) identify animals with compromised health, and 2) develop a health management plan around such animals.
The procedures to extract the data and provide informative data on individual animals was developed and could be used to exploit this technology further such as a reproductive management tool to help identify animals in heat.

(iii) Outcomes with economic potential

The novel technologies investigated for the routine recording of animal health data can be used to develop a management support tool for health.

(iv) Outcomes with national/policy/social/environmental potential

The overall objective of this project was to increase the rate of genetic gain in sheep, beef and dairy; the research undertaken as part of this study has been implemented into the national genetic evaluations which will in return allow for the selection of animals with superior performance on cost of production traits, thereby increasing profitability across all three sectors.

4 (b) Summary of Research Outputs

(i) Peer-reviewed publications, International Journal/Book chapters.

1. Carthy, T.R., Berry, D.P., Fitzgerald, A., McParland, S., Williams, E.J., Butler, S.T., Cromie, A.R. and Ryan, D. (2014). Risk factors associated with detailed reproductive phenotypes in dairy and beef cows. Animal 8, 695-703.
2. Berry, D.P. (2014). Genetics of bovine respiratory disease in cattle: can breeding programs reduce the problem? Animal Health Research Reviews 15, 151-156.
3. Berry, D.P., Coffey, M.P., Pryce, J.E., de Haas, Y., Lovendahl, P., Krattenmacher, N., Crowley, J.J., Wang, Z., Spurlock, D., Weigel, K., Macdonald, K., and Veerkamp, R.F. (2014). International genetic evaluations for feed intake in dairy cattle through the collation of data from multiple sources. Journal of Dairy Science 97, 3894-3905.
4. Berry, D.P., Wall, E., and Pryce, J.E. (2014). Genetics and genomics of reproductive performance in dairy and beef cattle Animal 8, 105-121.
5. Berry, D.P. and Evans, R.D. (2014). Genetics of reproductive performance in seasonal calving beef cows and its association with performance traits. Journal of Animal Science 92, 1412-1422.
6. Carthy, T.R., Ryan, D.P., Fitzgerald, A.M., Evans, R.D. and Berry, D.P. (2015). Genetic parameters of ovarian and uterine reproductive traits in dairy cows. Journal of Dairy Science 98, 4095-4106.
7. Hurley, A.M., Lopez-Villalobos, N., McParland, S., Kennedy, E., Lewis, E., O'Donovan, M., Burke, J.L., and Berry, D.P. (2016). Inter-relationships among alternative definitions of feed efficiency in grazing lactating dairy cows. Journal of Dairy Science 99, 468-479.
8. McHugh, N., Berry, D.P., and Pabiou, T. (2016). Risk factors associated with lambing traits. Animal 1, 89-95.
9. Carthy, T.R., Ryan, D.P., Fitzgerald, A.M., Evans, R.D. and Berry, D.P. (2016). Genetic relationships between detailed reproductive traits and performance traits in Holstein-Friesian dairy cattle. Journal of Dairy Science 99, 1286-1297.
10. McHugh, N., Pabiou, T., Wall, E., McDermott, K., and Berry, D.P. (2017). Impact of alternative definitions of contemporary groups on genetic evaluations of lambing traits. Journal of Animal Science 95, 1926-1938.
11. McHugh, N., Pabiou, T., McDermott, K., Wall, E. and Berry, D.P. (2017). Impact of birth and rearing type, as well as inaccuracy of recording, on pre-weaning lamb phenotypic and genetic merit for live weight. Translational Animal Science. 1, 137-145.
12. O'Brien, A., McHugh, N., Wall, E., Pabiou, T., McDermott, K., Randles, S., Fair, S., and Berry, D.P. (2017). Genetic parameters for lameness, mastitis and dagginess in a multi-breed sheep population. Animal. 11, 911-919.
13. Byrne, D.T., Berry, D.P., Esmonde, H., and McHugh, N. (2017). Temporal, spatial, inter- and intra- cow repeatability of thermal imaging. Journal of Animal Science 95, 970-979.
14. Kelleher, M., Buckley, F., Evans, R.D., and Berry, D.P. (2016). Additive genetic, non-additive genetic and permanent environmental effects for female reproductive

performance in seasonal calving dairy females. Irish Journal of Agricultural and Food Research 55, 10-23.
15. Hurley, A.M., Lopez-Villalobos, N., McParland, S., Lewis, E., Kennedy, E., O'Donovan, M., Burke, J.L., and Berry, D.P. (2017). Genetics of alternative definitions of feed efficiency in grazing lactating dairy cows. Journal of Dairy Science 100, 5501-5514.
16. Hurley, A.M., Lopez-Villalobos, N., McParland, S., Lewis, E., Kennedy, E., O'Donovan, M., Burke, J.L., and Berry, D.P. (2018). Characteristics of feed efficiency within and across lactation in dairy cows and the effect of genetic selection. Journal of Dairy Science 101, 1267-1280.
17. McHugh, N., McGovern, F., Creighton, P., Pabiou, T., McDermott, K., Wall, E., and Berry, D.P. (2019). Mean difference in live-weight per incremental difference in body condition score estimated in multiple sheep breeds and crossbreds. Animal 13, 549-553.
18. Byrne, D.T., Berry, D.P., Esmonde, H., and McHugh, N. (2018). Investigation of the relationship between udder quarter somatic cell count and udder skin surface temperature of dairy cows measured by infrared thermography. Journal of Animal Science 96, 4458-4470.
19. Byrne, D.T., Esmonde, H., Berry, D.P., McGovern, F., Creighton, P., and McHugh, N. (2019). Sheep lameness detection from individual hoof load. Computers and Electronics in Agriculture 158, 241-248.
20. Byrne, D.T., Berry, D.P., Esmonde, H., McGovern, F., Creighton, P. and McHugh, N. (2019). Infrared thermography as a tool to detect hoof lesions in sheep. Translational Animal Science 3, 577-588.

(ii) Popular non-scientific publications and abstracts including those presented at conferences

1. Berry et al. (2013) Genetics of Health and Disease. ICBF Industry Consultation Meeting. 2nd August 2013.
2. Carthy et al. (2013) Risk factors associated with reproductive tract status. EAAP Meeting 2013 Nantes France.
3. McHugh et al. (2014) Genetics of foot lesion scores in sheep. Agricultural Research Forum 10th - 11th March 2014.
4. Carthy et al. (2014) Genetics of detailed reproductive traits in Irish dairy cattle. Agricultural Research Forum 10th - 11th March 2014.
5. Berry et al. (2014) Heritable genetic variation exists in susceptibility to bovine viral diarrhea in dairy and beef cattle. Agricultural Research Forum 10th - 11th March 2014.
6. Berry et al. (2014) Genetics of Health. ICBF Industry Consultation Meeting. 27th May 2014.
7. Carthy et al. (2014) Genetic associations between detailed reproductive traits and milk production in dairy cows. International Cow Fertility Conference 18-21 May 2014, Westport, Ireland.
8. Carthy et al. (2015) Genetic relationships between detailed reproductive traits and milk production in dairy cows. Agricultural Research Forum 2015.

9. Carthy et al. (2015) Genetic relationships between detailed reproductive traits with body condition score and carcass traits in dairy cows. Agricultural Research Forum 2015.
10. Carthy et al. (2015) Regional heritability mapping to identify genomic regions associated with reproductive traits in Holstein-Friesian bulls. Agricultural Research Forum 2015.
11. Carthy et al. (2014) Genetic Correlations among Detailed Reproductive Traits, Traditional Reproductive Traits and Milk Production in Irish Dairy Cows Proceedings, 10th World Congress of Genetics Applied to Livestock Production.
12. Hurley et al. (2015) Inter-relationships among alternative definitions of feed efficiency in grazing lactating dairy cows. Agricultural Research Forum 2015.
13. Hurley et al. (2015) Inter-relationships among alternative definitions of feed efficiency in grazing lactating dairy cows across parities and lactation stages. Agricultural Research Forum 2015.
14. Hurley et al. (2014) Phenotypic correlations among alternative definitions of feed efficiency in grazing lactating dairy cows across parities and lactation stages. New Zealand Society of Animal Production 2014.
15. Hurley et al. (2014) Genetics of Alternative Definitions of Feed Efficiency in Grazing Lactating Dairy Cows. Proceedings, 10th World Congress of Genetics Applied to Livestock Production.
16. McHugh et al. (2014) Genetics of sheep health traits. Proceedings, 10th World Congress of Genetics Applied to Livestock Production.
17. Hurley et al. (2015) Phenotypic correlations among alternative definitions of feed efficiency in grazing lactating dairy cows across parities and lactation stages. New Zealand Society of Animal Production 2015.
18. McHugh et al. (2015) Comparison of across countries sheep breeding objectives in New Zealand and Ireland. EAAP Meeting 2015 Warsaw Poland.
19. McHugh et al. (2016) Genomic selection for a multi-breed sheep population in Ireland. EAAP Meeting 2016 Belfast.
20. Byrne et al. (2016) Spatial inter and intra repeatability of thermal imaging in cattle. EAAP Meeting 2016, Belfast, Ireland.
21. Berry et al. (2017) The Dairy Cow in 50 years Symposium. ADSA Annual Conference USA.
22. Berry et al. (2018) Genetics of (feed) efficiency. BSAS Annual Meeting 2018 Dublin.
23. Byrne et al. (2018) Using thermal imaging to detect lameness in sheep in an agricultural environment. American society of agricultural and biological engineers meeting 2018, Detroit, Michigan, USA.
24. Byrne et al. (2018) Investigation of the relationship between quarter somatic cell count and udder skin surface temperature of dairy cows measured by infrared thermography. BSAS meeting 2018, Dublin Ireland.
25. Byrne et al. (2017) Using engineering tools to detect lameness in sheep. International manufacturing conference 34, 2017, Sligo, Ireland.

26. McHugh et al. (2018) Breeding the ideal ewe for the future. BSAS meeting 2018, Dublin Ireland.
27. McHugh et al. (2018) Considerable heritable variability exists in lamb litter weight relative to ewe weight. World Congress Genetics Applied to Livestock Production, NZ 2018.

(iii) National Report

None

(iv) Workshops/seminars at which results were presented

1. SheepOpenday Teagasc Athenry 2014, 16th September 2014
2. ICBF Industry Meeting, 13th October 2014
3. Backweston Research Seminar, 15th October 2014
4. Agricultural Society Dairy Seminar, 22nd October 2014
5. Livestock Improvement Seminar, Hamilton, New Zealand, 17th November 2014
6. Postitive farmers conference, Cork, 10th January 1015
7. Dairy seminar, Urguary, 15th April 2015
8. AgResearch Seimar, Dunedin, New Zealand 4th June 2015
9. Sheep2015 Teagasc Athenry, 20th June 2015
10. Joint Animal Meetings 6th July 2015
11. Virginia show, Cavan, 13th August 2015
12. Liverpool University seminar, 11th September 2015
13. In-calf, Australia, 4th October 2015
14. National Beef Conference, Westmeath 13th October 2015
15. AbacusBio Seminar, Dunedin, New Zealand 21st October 2015
16. NCBC UK tour, 11th November 2015
17. National Sheep Conference, Galway, 2nd February 2016
18. Joint Ireland-UK sheep breeding meeting, 15th February 2016
19. ICBF Industry Meeting, 25th April 2016
20. UL post-graduate day, 4th May 2016
21. Sheep Ireland Industry Meeting, 5th May 2016
22. European Angus Forum, Azores 22nd May 2016
23. Aberdeen Angus Association, Scotland, 2nd June 2016
24. Workshop with Teagasc education staff, 12th July 2016
25. Workshop with Teagasc sheep advisors, 12th October 2016
26. Progressive genetics AGM, 10th November 2016
27. Beef breeding seminar Naas, 21st November 2016
28. Moorepark Science Day, 15th November 2016
29. Bermingham conference on feed efficiency, 6th January 2017
30. Rathkeale Teagasc seminar, 31st January 2017
31. Teagasc Beef steering group meeting, 20th February 2017
32. Moorepark Agri-aware day, 10th March 2017
33. Sheep Ireland industry meeting, 4th April 2017

34. Suckler Breeding Event, Carnew Mart, 16th April 2017
35. Sheep Advisors in-service training , 15th June 2017
36. Teagasc Sheep Openday, 20th June 2017
37. Moorepark 2017 Dairy openday, 4th July 2017
38. Presentation to British Texel Society, 11th July 2017
39. Annual Walsh fellowship seminar, 9th November 2017
40. Moorepark Agri-aware day, 29th March 2018
41. Athennry sheep open day 2018, 7th August 2018
42. iTexel Conference, UK, 17th October 2018
43. Burren Winterage event, 28th October 2018
44. ICBF Genetics conference 2018, 6th December 2018

(v) Intellectual Property applications/licences/patents

None

(vi) Other

None

5. Scientists trained by Project

Total Number of PhD theses: 3

1. *Tara Carthy*

Main supervisors: Donagh Berry (Teagasc) and Roy Sleator (UCD).
Title: Genetic and genomic of detailed reproductive traits in dairy and beef cattle.
Submission date: 1st October 2015

2. *Thomas Byrne*

Main supervisors: Nóirín McHugh (Teagasc) and Harry Esmonde (DCU).
Title: Use of infrared thermography to detect health incidences in an agricultural setting.
Submission date: 31st January 2019

3. *Alan Hurley*

Main supervisors: Donagh Berry (Teagasc) and Nicolas Lopez-Villalobos (Massey University, NZ)
Title: Genetics of alternative definitions of feed efficiency in grazing lactating dairy cows.
Submission date: 1st December 2017

Total Number of Masters theses: 0

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
Teagasc	2	1.376
ICBF	4	0.683
DCU	1	0.767
Total	**7**	**2.826**

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	0	
PhD students	2	8.00
Masters students	0	
Temporary researchers	0	
Other	0	
Total	**2**	**8.00**

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
NA	

9. Project Expenditure

Total expenditure of the project:	€ 269,519.31
Total Award by DAFM:	€288841.20
Other sources of funding including benefit in kind and/or cash contribution(specify):	€28,000.00

Breakdown of Total Expenditure

Category	Teagasc	ICBF	DCU	UCD	Total
Contract staff					
Temporary staff					
Post doctorates					
Post graduates	175,999.97				175,999.97
Consumables	1,414.76				1414.76
Travel and subsistence	5,029.68	3,200.00	1,942.03		10171.71
Sub total	182,444.41	3,200.00	1,942.03	0.00	187586.44
Durable equipment	7,805.79				7805.79
Other	17851.15				17851.15
Overheads	54,733.32	960.00	582.61		56275.93
Total	**262,834.67**	**4,160.00**	**2,524.64**	**0.00**	**269519.31**

10. Leveraging

In the original proposal two PhDs were to be recruited to the project, however through additional funding from a SFI project an additional PhD was recruited to the project. Additional funding was made available by both ICBF and Sheep Ireland which allowed for animals that were deep phenotyped as part of this project to be genotyped as well.

11. Future Strategies

The routine (i.e. growth rate and fertility data) and novel phenotypes (i.e. feed intake and health data) generated as part of this project are housed in the national databases and is available for use in future research projects. The generation of the novel feed intake data on sheep has resulted in members of the project team collaborating on two recently funded European projects (i.e. ERA-NET and a Horizon2020 project). The research conducted in this project is also built upon in on-going DAFM stimulus projects (i.e. MultiRepro and GreenBreed). Results from the present study have been presented widely at both a national and international level.

12. Consent to Publish Final Report on the DAFM Website and/or Through Other Dissemination channels

I consent to this report being made available to the public, through the Department's website and other dissemination channels.

Yes X☐ No ☐

13. Declaration

I declare that the information contained in this final report is complete and true to the best of my knowledge and belief.

Signed:  Project Coordinator

Date: 08/08/2019