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

Food Institutional Research Measure

Final Report

Genetic selection for improved milk and meat product quality in dairy beef and sheep (BreedQuaity)

DAFM Project Reference No: 11/SF/311

Start date: 01/11/2012

End Date: 30/04/2019

Principal Coordinator and Institution: Donagh Berry, Teagasc
Email: Donagh.berry@teagasc.ie

Collaborating Research Institutions and Researchers:
Sinead McParland, Teagasc
Ruth Hamill, Teagasc
Maeve Henchion, Teagasc
Torres Sweeney, University College Dublin
Mary McCarthy, University College Cork
Andrew Cromie, Irish Cattle Breeding Federation

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	6X	7

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

Priority Area (s)	**I**

Key words: *genetics, product quality, milk, meat*

1. Rationale for Undertaking the Research

Product quality can add value at the producer and processor level; having greater knowledge of more in-depth phenotypes for product quality can increase therefore profit. Prior to this project no measure of product quality (other than the macro-measures of product quality like fat and protein composition in milk and EUROP conformation score in cattle and sheep) were included in the national breeding objectives for cattle and sheep. Therefore, the national breeding objectives were sub-optimal and thus genetic gain in profit was not being maximised in Ireland. This project attempted to address this shortcoming.

To breed for product quality one needs: 1) routine access to large quantities of accurately predicted measures of product quality; 2) estimates of the contribution of genetics to phenotypic differences necessary to identify genetically elite animals in national genetic evaluations; 3) knowledge of the impact of altering product quality on product portfolio and post-slaughter meat management systems; and 4) knowledge of the weighting to put on product quality in national breeding objectives relative to other performance traits. All these points were addressed in this study. As future breeding schemes will rely more heavily on genomic information, regions of the genome coding for genomic variation in product quality were also explored.

The ability of primary and secondary processors to optimise milk and meat management systems, enhance consistency in quality and differentiate on the basis of quality, and create novel defined quality products will be enhanced. Consumers naturally favour products with consistently improved quality and with superior human health attributes and are willing to pay a premium for higher quality. Meeting this growing consumer demand will increase market share and margins of dairy and red meat products and thereby increase profit in these sectors for Irish producers and processors.

2. Research Approach

project began with a prioritisation of product quality traits in dairy, beef and sheep through in-depth consultation with stakeholders. Subsequent tasks were separated into dairy, beef, and sheep product quality, with a concluding task on dissemination. Each of the main research tasks were subdivided into: 1) development of rapid measures; 2) quantification of the contribution of genetic variability to the observed variability in the traits; 3) identification of genomic regions associated with different measures of product quality; 4) how to incorporate the traits into breeding objectives, and 5) impact on product portfolio and post-slaughter management.

The data used in the project was either collected during the project itself or was based on national data already available. The project exploited Ireland's leading scientific knowledge on milk and meat processing, statistical genetics, and molecular genetics. The close integration of the ICBF in this project ensures that: a) the project stayed focused on development of tools that can be implemented by industry, and b) the research results were rapidly disseminated and, where agreed, implemented into the national breeding strategies of each sector.

3. Research Achievements/Results

- Approaches based on stakeholder engagement could be used as a complement to traditional methods of determining the relative on traits within breeding objective.
- The potential of infrared spectroscopy analysis of routinely taken milk samples to predict some milk quality parameters was clearly demonstrated; this was based on 730 milk samples analysed for 28 different quality parameters
    - Accuracy of prediction (correlation between true and predicted values) of protein fractions ranged from 0.57 (K-casein) to 0.76 (Total β-lactoglobulin). Accuracy of prediction of free amino acids ranged from 0.45 (Serine) to 0.85 (Argenine). Accuracy of colour prediction ranged from 0 (redness) to 0.77 (yellowness).
    - Accuracy of prediction of individual proteins ranged from 0.39 (beta lactoglobulin-a) to 0.69 (total lactoglobulin). Accuracy of prediction of free amino acids ranged from 0.22 (Threonine) to 0.75 (Glycine) while accuracy of heat coagulation properties ranged from 0.50 (curd firmness 60 minutes after rennet addition) to 0.74 (rennet coagulation time). Accuracy of prediction of milk yellowness, milk pH, casein micelle size and heat stability were 0.71, 0.84, 0.36, and 0.68, respectively.
- This potential predictive ability of milk quality was also demonstrated using real-life field data where the milk from cows predicted to be divergent for milk quality parameters was sampled and product made.
- *Exploitable genetic variability existed in the milk quality parameters*
    - The heritability estimates for gold standard protein fractions ranged from 0.04 (β-CN) to 0.61 (total LG) whereas, the heritability estimates for MIRS-predicted protein fractions were higher overall with a smaller range (0.19 for α-lactalbumin to 0.46 for β-LG A).
    - The heritability estimates for gold standard FAA ranged from 0.05 for Asparagine (Asp) to 0.58 for Serine (Ser). Similar to MIRS-predicted protein fractions, the heritability estimates for MIRS-predicted FAA had a smaller range (0.15 for glycine to 5.05 for total FAA).
    - Heritability estimates for MIRS-predicted milk colour traits were 0.29 (L*), 0.09 (a*), and 0.35 (b*). Repeatability estimates were 0.39, 0.18, and 0.38 for L*, a*, and b*, respectively. When MIRS-predicted b* was adjusted for fat concentration, heritability and repeatability estimates were 0.25 and 0.32, respectively.
    - Regarding MIRS-predicted milk processing attributes, heritability estimates were 0.16 (HCT), 0.27 (a60 and pH), 0.28 (RCT), 0.31 (CMS), 0.36 (a30), and 0.43 (k20). The repeatability estimates for MIRS-predicted milk processing traits ranged from 0.34 (a60) to 0.45 (a30), with the exception of 0.29 (HCT) and 0.53 (k20).
- While the predictive ability of meat quality in cattle and sheep from spectroscopy measures was poor, clear inter-animal genetic variability (including breed differences) was evident for tenderness, flavor and juiciness.
    - The estimated heritability for tenderness, juiciness and flavor are 0.09, 0.09 and 0.13 with a coefficient of genetic variation of 6-10%.
- Validation of meat quality genetic evaluations was undertaken:
    - A demonstration was undertaken at the Grange Open day 2014 where 102 participants were asked to score their eating experience from two meat samples of Tully animals divergent for meat eating quality. Very good concordance was achieved

between the consumer score for eating experience and estimated genetic merit based on the trained assessors. Across this sample, 54% of respondents said that the steak from the animal with poor genetic merit for tenderness scored worse than the steak with the good genetic merit for tenderness; 29% said the contrary.

- Genomic analyses of imputed whole genome sequence data on the sensory data revealed no genomic variant that would contribute to a noticeable difference among animals.

4. **Impact of the Research**

- The first ever national genomic evaluations globally for meat eating quality in a multibreed population of cattle was released (in conjunction with Meat Technology Ireland who also provided data to supplement the data collected in the present study). These evaluations are currently freely available for individual bulls (https://www.icbf.com/meat-eating-quality/)
    - The outcome or impact from this output is the ability to improve the mean eating quality of the national cattle herd through sustainable breeding programs
- New knowledge was generated on the predictability of product quality using non-destructive infrared technology – this preliminary research was used to secure additional funding to advance the approach (e.g., vistamilk)
- Knowledge was generated on the contribution of genetic differences to observable genetic differences in meat eating quality – this information was used to support the study deign for the Meat Technology Ireland platform on the genetics of meat eating quality
- Additional funding has also been leveraged from the developments in Breedquality, most notably that of MTI which is an €8m center funded by industry and Enterprise Ireland as well as the €9m project INTAQT.

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

- University of Padova
- INRAE (lead of EU project INTAQT)

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

- First ever national genomic evaluations for meat eating quality in a multibreed cattle population

(iii) Outcomes with economic potential

- Point of differentiation internationally with genomic evaluations for meat eating quality and detailed milk quality parameters and thus the ability to predict product quality of individual animals

- Over-time, if the nationally available genomic evaluations for meat quality are adopted, the mean eating quality of Irish beef should improve

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

- Including meat eating quality and milk quality in national breeding programs can help mitigate any potential deterioration in these parameters thus contributing to more sustainable breeding programs

4 (b) Summary of Research Outputs

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

- Visentin, G, DP Berry, A Costa, A McDermott, M De Marchi, S McParland (2022) Breeding for improved protein fractions and free amino acids concentration in bovine milk. Journal of Animal Breeding and Genetics 139 (5), 517-529
- Scarso, S, S McParland, G Visentin, DP Berry, A McDermott, M De Marchi. (2017) Genetic and nongenetic factors associated with milk color in dairy cows. Journal of Dairy Science 100 (9), 7345-7361
- McDermott, A, M De Marchi, DP Berry, G Visentin, MA Fenelon, S. McParland (2017) Cow and environmental factors associated with protein fractions and free amino acids predicted using mid-infrared spectroscopy in bovine milk. Journal of dairy science 100 (8), 6272-6284
- Visentin, G, S McParland, M De Marchi, A McDermott, MA Fenelon, D.P. Berry (2016) Processing characteristics of dairy cow milk are moderately heritable. Journal of Dairy Science 100 (8), 6343-6355
- Visentin, M De Marchi, DP Berry, A McDermott, MA Fenelon, M Penasa, S. McParland. (2017) Factors associated with milk processing characteristics predicted by mid-infrared spectroscopy in a large database of dairy cows. Journal of dairy science 100 (4), 3293-3304
- McDermott, G Visentin, S McParland, DP Berry, MA Fenelon, M. de Marchi (2017). Effectiveness of mid-infrared spectroscopy to predict the color of bovine milk and the relationship between milk color and traditional milk quality traits. Journal of Dairy Science 99 (5), 3267-3273
- Visentin, G, A McDermott, S McParland, DP Berry, OA Kenny, A Brodkorb, M. De Marchi. (2016). Prediction of bovine milk technological traits from mid-infrared spectroscopy analysis in dairy cows. Journal of Dairy Science 98 (9), 6620-6629
- Cama-Moncunill R, J Cafferky, C Augier, T Sweeney, P Allen, A Ferragina. (2020). Prediction of Warner-Bratzler shear force, intramuscular fat, drip-loss and cook-loss in beef via Raman spectroscopy and chemometrics. Meat science 167, 108157
- Cafferky, J, T Sweeney, P Allen, A Sahar, G Downey, AR Cromie. (2018) Investigating the use of visible and near infrared spectroscopy to predict sensory and texture attributes of beef M. longissimus thoracis et lumborum. Meat science 159, 107915

- Cafferky, J, RM Hamill, P Allen, JV O'Doherty, A Cromie, T Sweeney. (2017) Effect of Breed and Gender on Meat Quality of M. longissimus thoracis et lumborum Muscle from Crossbred Beef Bulls and Steers. Foods 8 (5), 173

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

- Visentin, M De Marchi, A Mcdermott, DP Berry, M Penasa, S Mcparland. 2015 Phenotypic characterization of milk processing traits predicted by mid-infrared spectroscopy. Book of Abstracts of the 67th Annual Meeting of the EAAP
- McDermott, G Visentin, S McParland, DP Berry, MA Fenelon, M. de Marchi (20145) Prediction of proteins including free amino acids in bovine milk by mid-infrared spectroscopy. Book of Abstracts of the 67th Annual Meeting of the EAAP
- McDermott, G Visentin, S McParland, DP Berry, MA Fenelon, M. de Marchi (2014). Mid infrared spectroscopy to predict important milk quality traits in Irish cows. World Congress on genetic Applied to Livestock Production.
- Visentin G, M De Marchi, A Mcdermott, DP Berry, M Penasa, S Mcparland. (2014) Genetics of milk coagulation properties predicted by milk mid infrared spectroscopy analysis. World Congress on genetic Applied to Livestock Production.
- Kearney F, A. Moloney, R. Prendiville, P. Allen, B. Meredith and S. Conroy. 2014. Phenotypic and Genetic Analysis of Meat Eating Quality Traits in Irish Cattle. World Congress on genetic Applied to Livestock Production.
- Ryan, AT MT, Campos V, Hanrahan JP, Hamill RM and Sweeney T. 2018. Identification of novel regulatory polymorphisms in the promoter region of differentially expressed candidate genes involved in carcass and meat quality traits in lamb. British Society of Animal Science
- Campos, A.T. V, Hanrahan JP , Allen P, Keady TWJ, Ryan MT, Hamill RM and Sweeney T. 2018. Detection of differentially expressed genes in the M. longissimus thoracis et lumborum from full-sibling lambs divergent for fatness. British Society of Animal Science
- Alam T, Campos V, Hanrahan JP, Allen P, Harrison SM, Keady TWJ, Rayan MT, Hamill RM and Sweeney T. 2018. Identification of differentially expressed genes in the M. longissimus thoracis et lumborum from full-sibling lambs divergent for fatty acid profile. British Society of Animal Science
- Alam T, Campos V. de, Hanrahan JP , Allen P, Keady T, Hamill RM, Sweeney T. 2018. Transcriptional analysis of ovine M. Longissimus thoracis et lumborum for genes involved in carcass and meat quality traits. British Society of Animal Science
- Cafferky, J, V Campos, A Sahar, R Hamill, P Allen, A Cromie, T Sweeney (2017). Eating quality of muscle from Crossbred beef bulls and steers. 63rd International Congress of Meat Science and Technology:
- Cafferky, J, T Sweeney, P Allen, A Sahar, GDA Cromie, RM Hamill (2017). Investigating the use of visible and near infrared spectroscopy to predict sensory and texture attributes of beef. 63rd International Congress of Meat Science and Technology

(iii) National Report

(iv) Workshops/seminars at which results were presented
McDermott, A and G Visentin, (2015). Milk quality. Moorepark Open Day
Presented at many ICBF industry days

(v) Intellectual Property applications/licences/patents

(vi) Other

5. Scientists trained by Project

Total Number of PhD theses: 3

- Visentin, 2018. Genetic and nongenetic variation of milk processing characteristics in Irish and Italian dairy cattle. University of Padova.
- McDermott, 2018. Genetic selection for improved milk quality in Irish dairy cattle. University of Padova.
- Cafferky, 2018. Genetic selection for improved meat quality in Irish dairy cattle. University College Dublin.

Total Number of Masters theses: 0

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
Teagasc	10	3.9
UCD	3	9.6
ICBF	5	2.14
Total	**18**	**15.62**

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	6	17.24
PhD students	3	4.33
Masters students	0	
Temporary researchers		
Other		
Total	**9**	**21.57**

8. Involvement in Agri Food Graduate Development Programme

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

9. Project Expenditure

Total expenditure of the project:	€1,038,657.81
Total Award by DAFM:	€1,048,758.24
Other sources of funding including benefit in kind and/or cash contribution(specify):	€0

Breakdown of Total Expenditure

Category	Teagasc Ashtown	Teagasc, Moorepark	UCD	ICBF	UCC	Total
Contract staff	191,168.54		127,790.98	45,162		364121.5
Temporary staff						0
Post doctorates						0
Post graduates	3,666.66	71,500	45,916.56			121083.2
Consumables	16,281.12	21,274.31	98,591.24			136146.7
Travel and subsistence	28,120.39	9,532.08	8,312.06	1,456.23	96.62	47517.38
Sub total	239,236.71	102,306.39	280,610.84	46,618.43	96.62	668869
Durable equipment	19,525					19525
Other	57023.43	911.53	30,223.56	68,160		156318.5
Overheads	71,771	30,691.92	77,468.1	13,985.53	28.99	193945.5
Total	**387.556.13**	**133,909.84**	**388,302.5**	**128,763.96**	**125.61**	**1038658**

10. Leveraging

The data generated in this project has been used by several others but also helped leverage additional funding from other source like Enterprise Ireland and Horizon Europe.

11. Future Strategies

Meat from genotyped cattle continue to be assessed for tenderness, juiciness and flavour to update the national genomic evaluations.

Sensors in VistaMilk are being developed for some of the milk quality parameters investigated within