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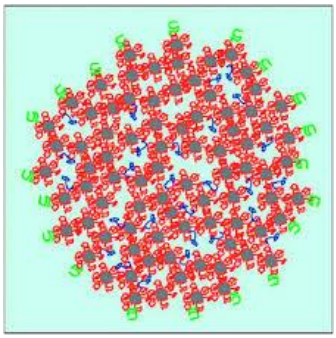
Precision Nutrition for improved animal productivity, product quality and environmental sustainability



Casein micelle model proposed by Dalgleish (2011)

Key external stakeholders:

Irish dairy farmers, milk processors, animal nutrition industry

Practical implications for stakeholders:

International research has reported on the nutritional factors influencing dairy cow production performance, milk product quality, enteric methane emissions and Nitrogen Utilisation Efficiency (NUE). The Irish dairy industry is however unique due to its pasture-based diet, and thus this project generated information specifically for Irish dairy farmers, milk processors and the animal nutrition industry. This project investigated the effect of various pasture-based dietary regimens on the quality of milk for the production of high value-added cheese and infant formula.

Main results:

- During periods of grass deficit in spring offering lower daily quantities of grass to lactating dairy cows (daily herbage allowance; DHA) reduced milk yield and milk protein concentration, but had little other effect on milk composition or processing characteristics.
- A grazed grass only diet (GRO), a grazed grass plus white clover diet (GRC) and an indoor TMR diet (TMR) were compared. Milk from the GRO treatment had a higher concentration of protein and casein, and had stronger rennet gelation characteristics than TMR milk. Milk from the two grazing systems had a higher mozzarella cheese-yielding capacity than TMR milk, the cheese was more yellow, and the cheese became more fluid and flowable on heating to 95^{o}C.
- Understanding the rumen microbiome and its connection to the ruminant itself is important for producing quality products, increasing profitability and reducing environmental impacts. Examining the rumen microbiome can identify the effects of diet on the microbiome and in turn, the effects on milk yield, protein percentages, urea percentage (used as a Non Protein Nitrogen [NPN] indicator) and milk protein yield.

Opportunity / Benefit:

The dairy farmer must continue to focus on producing high quality milk in an environmentally sustainable manner from a grass-based system. The optimum nutritional strategy must be elucidated in order to produce higher processability milk over a longer period of time in an environmentally sustainable way. This project will generate key data on the effects of dairy cow nutrition, in an Irish context, on milk composition and processability.

Collaborating Institutions:

AFBI NI
UCC
Nutribio (animal nutrition company)

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1. Project background:

Much work has been done internationally looking at the effects of diet on milk composition and processability. In Ireland our dietary regime is quite unique due to our ability to efficiently grow large quantities of high quality pasture. In 2009, 56% of whole milk produced in Ireland was utilised in the manufacture of butter and 31% in the production of cheese, and these proportions are increasing over time. Hence, the suitability of milk for manufacture into these products (processability) is increasing in importance. It is necessary to have a complete overview of the effects of various grass-based diets on milk composition and milk processability, especially for the production of high value-added cheese and infant formula. The differences in milk and product characteristics obtained from different feeding systems may provide a foundation for product differentiating parameters suited to different consumers, processors and markets.

2. Questions addressed by the project:

- Compared to outdoor grazing, does a total mixed ration (TMR) diet offered indoors to lactating dairy cows give rise to
    - Milk with a different gross composition and mineral content
    - Milk which gives altered mozzarella cheese yield and quality
    - Milk which gives altered skim milk powder quality
- Do two different outdoor grazing strategies, namely grazing perennial ryegrass only (GRO) compared to mixed grass plus white clover swards (GRC), give rise to milk differing in processability
- Does offering different allowances of herbage (daily herbage allowance, DHA) alter the milk composition and processability
- Review the state of the art in terms of the rumen microbiome, with particular reference to methane and NUE

3. The experimental studies:

Thirty-six spring-calving dairy cows were assigned to three different herds which were placed on different daily herbage allowance (DHA) for 6 weeks in early lactation. The three DHA were 11.8 (low L-DHA), 14.4 (medium M-DHA) and 15.0 (high H-DHA) kg DM/cow, respectively >3.5 cm. Effects on milk composition and processability (e.g. rennet gelation, heat coagulation time) were examined throughout lactation. Milk was sampled at 10-day intervals during early lactation. Thereafter, milk was sampled at 1-3 week intervals for the remainder of lactation.

Sixty spring-calving dairy cows were allocated to one of three feeding systems. The feeding systems, imposed from mid-February to November, were: grazing on perennial ryegrass (*Lolium perenne* L.) pasture (GRO), grazing on perennial ryegrass and white clover (*Trifolium repens* L.) pasture (GRC), or housed indoors and offered total mixed ration (TMR). During one study milk from each herd was collected on 10 separate occasions, at two or three weekly intervals, during summer and autumn. The milk from each herd was collected in a separate refrigerated bulk tank. A representative 2-L herd milk sample was withdrawn through the sampling port of each bulk tank into clean 2-L glass bottles and taken immediately to the laboratory for analysis. Milk was analysed for gross composition and elements over the period from June to early September, and from late September to late November. In the second study, bulk herd milks were collected in mid lactation (May- July) and late lactation (end September to start November), and evaluated for their Mozzarella cheese- and low-heat skim milk powder-making characteristics.

4. Main results:

Reducing DHA of a spring-calved herd from 15 to 11.8 kg DM per cow for 6 weeks in early lactation

- led to lower milk yield, milk solids yield and concentrations of total protein and casein

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- but had little, or no, effect on other aspects of composition (e.g. concentrations of fat, lactose, NPN, urea, elements or proportions of individual caseins), rennet gelation or heat stability at pH values 6.2-7.2

There was little, or no, impact of reducing DHA in early lactation on milk composition, rennet gelation or heat stability in mid lactation, in late lactation or during the entire lactation.

➔ Restricted grazing without concentrate supplementation can, within limits, be applied in early lactation with little consequence apart from the lower yields of milk and milk solids during the period.

GRO vs GRC vs TMR (Mozzarella cheese)

- Compared to TMR milk, GRO and GRC milks had higher concentrations of protein and casein, and lower concentrations of I, Cu and Se, higher cheese-yielding capacity, and produced cheese which had lower concentrations of the trace elements I, Cu and Se, and were visually more yellow in colour
- Cheese from GRO milk was more flowable and fluid on heating to 90-95^{o}C
- Otherwise, feeding systems had little, or no, effect on losses of milk fat and protein to whey, cheese composition or texture
  ➔ the higher yield and the melt characteristics of cheeses obtained from GRO milk may prove attractive from a manufacturer's perspective, although the market in general is more accustomed to eating white-coloured cheese varieties

GRO vs GRC vs TMR (low heat skim milk powder)

- Powder from the GRO or GRC feeding systems had a higher mean content of protein, lower contents of lactose, I, Cu and Se, and a more 'green-yellow' colour than the corresponding powder from TMR milk
- The GRO Reconstituted Skim Milk (RSM) had higher mean concentrations of protein and casein, lower concentrations of lactose and NPN and higher rennet-gel strength than TMR RSM. The levels of protein and NPN and rennet gel strength of GRC RSM were intermediate to GRO and TMR.
- Feeding system had little, or no, effect on the physicochemical characteristics, heat coagulation time or ethanol stability of the RSM, or the consistency characteristics of stirred yoghurt prepared from the RSM
  ➔ The lower lactose-to-protein ratio of the GRO and GRC powders may be more desirable from a nutritional and functional perspective in many applications, for example in recombined milks that are used for cheese manufacture or subjected to high heat treatment
  ➔ The difference in the elemental composition of the powders from the different feeding systems is of relevance when formulating dairy-based nutritional beverages, e.g., infant milk formula, with target levels of minerals.

Review paper: The rumen microbiome: a crucial consideration when optimising milk and meat production and nitrogen utilisation efficiency

- The review examines the impact of diet on bovine rumen function and outlined what is known about the rumen microbiome
- Citrus by-products, eg citrus pulp, can be used as an alternative to highly fermentable grains, preventing the excessive growth of Streptococcus bovis, and associated ruminal acidosis.
- One study identified Firmicutes:Bacteroidetes to be strongly correlated to milk fat yield. Higher percentages of Firmicutes compensated for the lower abundances of Bacteroidetes. A decreased abundance of Bacteroidetes in comparison to Firmicutes resulted in increased milk fat percentage.
- The microbiome controls the production efficiency of the animal, with certain pathways (such as those associated with methane production) resulting in energy loss in the animal
- The microbiome also affects end-product quality but also contributes to environmental pollution
  ➔ identifying certain metabolic pathways and further research into these pathways may determine the best diet for bovine ruminants in order to minimise energy loss, reduce methane production and increase nitrogen utilization efficiency

5. Opportunity/Benefit:

These results provide data on the differential effects that various diets for dairy cows have on milk composition, and subsequent effects on the production and quality of cheese and skim milk powder. It is necessary to have a complete overview of the effects of various grass-based diets on milk composition and milk processability, especially for the production of high value-added cheese and infant formula. The differences in milk and product characteristics obtained from different feeding systems may provide a foundation for product differentiating parameters suited to different consumers, processors and markets.

6. Dissemination:

The primary stakeholders for this research are Irish dairy farmers, milk processors and animal nutrition companies. The results of this project have been disseminated through the popular press and at the

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Teagasc Grass-Fed Dairy Conference, Teagasc Moorepark Open Day, as well as at scientific conferences and in scientific peer-reviewed publications.

Main publications:

Gulati, A., Galvin, N., Lewis, E., Hennessy, D., O'Donovan, M., McManus, J.J., Fenelon, M.A., Guinee, T.P. 2018. Outdoor grazing of dairy cows on pasture versus indoor feeding on total mixed ration: Effects on gross composition and mineral content milk during lactation. Journal of Dairy Science 101: 2710-2723

Gulati, A., Galvin, N., Kennedy, E., Lewis, E., McManus, J.J., Fenelon, M.A., Guinee, T.P. 2019. Effect of reducing daily herbage allowance during early lactation on composition and processing characteristics of milk from spring calved herds. International Dairy Journal 92: 69-76

Matthews, C., Crispie, F., Lewis, E., Reid, M., O'Toole, P.W., Cotter, P.D. 2019. The rumen microbiome: a crucial consideration when optimising milk and meat production and Nitrogen Utilisation Efficiency. Gut Microbes 10: 115-132

Popular publications:

Gulati et al., 2018. Effect of dairy cow feeding system on milk composition and processability. In: Proceedings of the Grass-Fed Dairy Conference, Naas, Co. Kildare, Ireland, 25th October 2018, 5 pages.

Gulati et al., 2018. Effect of dairy cow feeding system on milk composition during mid-to-late lactation: minerals and nitrogen fractions. In: Proceedings of the Grass-Fed Dairy Conference, Naas, Co. Kildare, Ireland, 25th October 2018, 1 page.

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