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Processing quality of milk - seasonal variation in milk composition and minimizing chemical residues

Key external stakeholders:
Dairy farmers, milk processors, National Dairy Council, Ornua

Practical implications for stakeholders:
Ireland is currently well recognised internationally for the production of very good quality milk and this premium quality status will need to be maintained, and improved upon, for the long-term future of the export market and the interests of the consumer. The removal of quotas is resulting in increased milk production. This will necessitate a focus on milk quality to ensure the production of premium quality milk for an extended manufacturing season. The 50% increase in milk production by 2020, as forecasted by *Food Harvest 2020* would equate to a 2.75 billion litre increase in milk production that would add value to primary output by about €700 million/year, with further benefits from increased dairy product values, export earnings and employment. This project has focused on identifying and optimally managing the factors impacting on the processing quality of raw milk produced in Ireland.

Main results:

Mean levels of a range of minerals in milk and their profile during lactation was determined. Mean concentrations of Mg, Mn, Fe, Co, Cu, Se, Mb, P, Ca and Zn in milk were 44µg/kg, 38µg/kg, 241µg/kg, 0.4 µg/kg, 39µg/kg, 18µg/kg, 113mg/kg, 915mg/kg, 1178mg/kg and 372mg/kg, respectively. Both dietary iodine supplementation and teat disinfection using iodine resulted in milk iodine concentrations exceeding common target values of 250 µg/kg. With milk iodine levels of approximately 200 µgkg in the absence of dietary and disinfection iodine, considered in association with a target level of 250 µg/kg, there is minimal flexibility for iodine supplementation, if target milk iodine concentrations are to be achieved. When the flukicide Rafoxanide was applied to lactating cows, Rafoxanide residues were carried over into the dairy products and were stable therein. This poses a serious challenge for industry and further research is required. Routine screening of approximately 25,000 milk samples and follow-up advice on problem solving has resulted in milk TCM being reduced to and maintained at the target levels of 0.03mg/kg in butter product.

Opportunity / Benefit:

As the industry develops and expands over the coming decade it will be vital that the clean, green image of the Irish dairy industry is maintained. Challenges such as variation in composition and the presence of various residues exist. Research such as that generated in this project and dissemination of that information, as conducted in this study will allow the dairy processing industry successfully meet these challenges.

Collaborating Institutions: Teagasc Moorepark Food research Centre, Teagasc Ashtown Food research Centre, University College Cork (UCC).

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External collaborators: Professor Alan Kelly (UCC)

1. Project background:

If dairy product manufacture is to be extended then milk compositional characteristics must be examined over the lactation profile. Also, some specific sectors within the industry require specific quality criteria, e.g. trichloromethane (TCM) levels of <0.03mg/kg in butter and <250 µg/kg of iodine in milk intended for use as a raw material for infant feed formula. Furthermore, the stability of veterinary drugs in milk and subsequent product is most important in contributing to the knowledge required for setting of MRLs (maximum residue limits). Products without MRLs are currently banned for use on milk producing animals, which is causing a problem for dairy farmers. Finally, it is necessary to package this information in a user-friendly mode. Much international research cannot be used directly by industry in Ireland, since Irish dairy production is unique in Europe due to its pasture-based production system. A number of Irish studies have also been completed focusing on processability of milk (Guinee and O'Brien, 2010; O'Brien and Guinee, 2011). However, there is now a challenge of producing an ever higher standard of milk quality from a modern cow within the setting of new milk production expansion on-farm and in light of recent changes in animal treatments and legislation.

2. Questions addressed by the project:

- Determine mineral profile of the national milk pool
- What is the effect of iodine fortified feed and teat disinfection practices of dairy cows on milk iodine concentration on milk iodine levels
- Research and review the pathway and residence time of veterinary drugs between milk and dairy product
- Monitor milk TCM residue at national level, continuing investigation of contributing factors and research methods for its reduction in Irish milk
- Produce DVD as a technology transfer tool in the area of milk quality

3. The experimental studies:

- Milk samples were collected from manufacturing milk storage silos at eight milk processing plants at approximately 3-weekly intervals. Mineral analysis of the milks was conducted by ICPMS (induction coupled plasma mass spectrometry).
- Thirty lactating cows were fed 7 kg, 3 kg (10 mg iodine/kg) and 0 kg of concentrate feed during 3 periods of 35 days each. During the first 14 days of each period, cows were on dietary iodine treatments only; during days 15–21, one of three teat disinfection treatments (n = 10) was applied (in addition to the dietary iodine treatments): non-iodine (chlorhexidine) post-milking spray; 0.5% iodine spray post-milking; 0.5% iodine spray pre- and post-milking. Cow milk yield was 21.3 kg/day. Individual cow milk samples were analysed for iodine concentration on 2 days at the end of each treatment period.
- Research followed the persistence and stability of the flukicide Rafoxanide residues during pasteurisation, separation and manufacture of dairy products cheese, butter and milk powder.
- In an attempt to reduce TCM residues in milk, a template procedure was developed, tried and tested on 43 farms (from 3 processing companies). This involved identifying farms with high TCM milk, applying corrective action in the form of advice and recommendations to reduce TCM and re-measuring milks from these farms. Trichloromethane in milk was measured by head-space gas chromatography with electron capture detector.
- Approximately 25,000 dairy farmer milk supplier samples were collected and analysed for TCM over each of 3 years. Suppliers of high TCM milks were identified. Causative factors were identified on-farm and advice for correction issued.
- Video clips and DVD of optimum milk production procedures on farms with medium and large cow herd sizes were produced.

4. Main results:

Mean levels of a range of minerals in milk and their profile during lactation was determined. Mean concentrations of Mg, Mn, Fe, Co, Cu, Se, Mb, P, Ca and Zn in milk were 44µg/kg, 38µg/kg, 241µg/kg, 0.4 µg/kg, 39µg/kg, 18µg/kg, 113mg/kg, 915mg/kg, 1178mg/kg and 372mg/kg, respectively. Both Mg and Ca were both influenced by stage of lactation. Mn was also affected by stage of lactation (increased with

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advanced lactation). It has been reported that Mn concentration of Finnish milk is s 30% higher in winter than in spring. Fe also increased with advancing lactation. A slight increase in Se and Mo was observed as lactation progressed. Cu levels in milk were consistent over time in the current study; Cu content is very much influenced by the feeding of cow (can be low in grass but high in feeds). P and Zn levels changed little. Some variation in Co was observed but no consistent effect of stage of lactation was evident.

Dietary supplementation of iodine at both 30 mg and 70 mg/day, when compared to the diet with no supplement, increased milk iodine concentrations significantly ($P<0.001$) from 449 to 1034 and 915 µg/kg, respectively. Teat disinfection both pre- and post-milking increased milk iodine concentration at each of the dietary supplementation levels of 0, 30 and 70 mg/day compared with a non-iodine teat disinfectant ($P<0.001$). Both dietary iodine supplementation and teat disinfection iodine increased milk iodine concentrations in an additive manner, exceeding common target values of 250 µg/kg. As both iodine treatments can occur simultaneously on farm, supplementation strategies should be monitored.

Results associated with the flukicide active ingredient Rafoxanide are as follows. The highest concentration of Rafoxanide residues detected in individual cows milk ranged from 249 to 627 µg/kg and occurred at 2–3 days post-treatment. Pasteurisation appeared to have little impact on the stability of the residues. Rafoxanide concentrated six-fold in the cheese compared to the starting milk (2070 vs. 349 µg/kg but was four times lower in whey (75 µg/kg. Rafoxanide residues were up to 14 times higher in butter than in the starting milk (5468 vs. 376 µg/kg). Residues were found to further concentrate in butter and cheese at longer storage and ripening times, respectively. Skim-milk powder was manufactured from skim milk, and residues were 10-fold higher than in the starting skim milk (5468 vs. 376 µg/kg) despite the 185°C temperature required for the process. Rafoxanide residues were stable in this skim-milk powder when stored at ambient temperature for at least 1 year. Results showed that detectable Rafoxanide residues were excreted in milk for 47 days, and concentrated in the fat-based products. In January 2013, new licensing arrangements regarding the treatment of animals with flukicides were introduced in the European Union. In the interest of animal welfare, and in order that the results from animal trials may be considered valid for inclusion in the development of regulations, it is necessary that such trials are undertaken in accordance with appropriate licensing arrangements. The legislative strategy required for obtaining such licences for such live animal trials with flukicides was identified and a blueprint for obtaining the appropriate licences and undertaking such experiments has been outlined as part of the work undertaken in this project.

TCM levels in butter are an important market-driven concern for the dairy industry. This issue has been addressed at Teagasc on an on-going basis in recent years. The TCM reduction strategy proved successful in significantly reducing the levels in milk in the farms tested, e.g. TCM was reduced from 0.006 to the target of 0.002 mg/kg ($P<0.05$). The strategy was then applied to farms who supplied milk to six Irish dairy processors with the objective of reducing TCM in those milks to a level of ≤0.002 mg/kg. Initially, milk tankers containing milks from approximately 10-15 individual farms were sampled and analysed and tankers with high TCM (>0.002 mg/kg) were identified. Individual herd milks contributing to these tankers were subsequently sampled and analysed and farms supplying high TCM identified. Guidance and advice was provided to the high TCM milk suppliers and levels of TCM of these milk supplies were monitored subsequently. A significant reduction (minimum $P<0.05$) in milk TCM was observed in 5 of the 6 dairy processor milks, while a numerical reduction in TCM was observed in the remaining processor milk.

Significant progress has been achieved. Figure 1 shows the gradual reduction of TCM in butter from 0.07 mg/kg in 2007 to 0.03 mg/kg in 2013. This was achieved through farm visits, advice on the correct practices allied with a vigorous advisory campaign through Teagasc and the dairy companies and, most importantly, an intensive analysis programme. Routine screening for TCM in both tanker milks and individual suppliers' milk resulted in analysis of approximately 25,000 milk samples annually from 2011 onwards.

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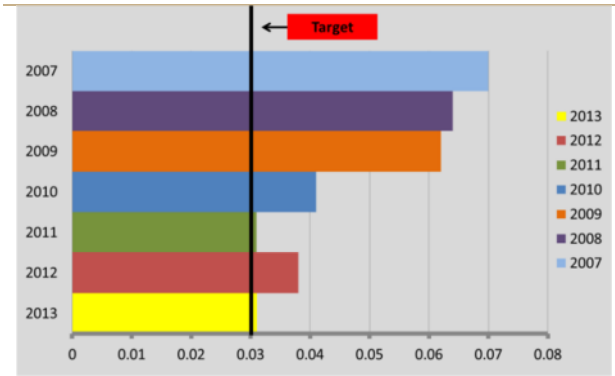

Figure 1. TCM Trend in Irish butter 2007-2013

5. Opportunity/Benefit:

As the industry develops and expands over the coming decade it will be vital that the clean, green image of the Irish dairy industry is maintained. New markets and new products, along with the need to link quality milk production to our seasonal supply will continue to impose new challenges to the industry. A strong research base in quality milk production and processing with solid links to the dissemination capacity of the Teagasc Dairy Advisory group and the key industry stakeholders will be vital if these challenges are to be addressed in a positive and adequate manner. Research such as that generated in this project and dissemination of that information, as conducted in this study will allow the dairy processing industry successfully meet these challenges.

6. Dissemination:

All of the information generated from the project was disseminated to other researchers, Ornua and Department of Agriculture personnel, Irish regulatory bodies, most Irish milk processors and milk purchasers, AHI (Animal Health Ireland), ICBF (Irish Cattle Breeding Federation), ICOS (Irish Co-operative Organization Society) and IMQCS (Irish Milk Quality Cooperative Society) personnel, through the 'Milk and Product Quality Forum' that meets bi-annually (spring and autumn).
A milk quality conference was held in December, 2013 at which information from the project was disseminated.
A milk quality workshop was held in December, 2014 at which different aspects of this work has also been disseminated.
In-service training sessions are held annually and this information has also been disseminated through these sessions to Teagasc Advisory personnel.
Teagasc web page: http://www.agresearch.teagasc.ie/moorepark/milkquality/
Teagasc video clips on milk quality: http://www.agresearch.teagasc.ie/moorepark/milkquality/videos.asp

Main publications:

O'Brien, B., Gleeson, D. and Jordan, K. (2013). Iodine concentrations in milk. *Irish Journal of Agricultural and Food Research*, **52** 209-216.
Ryan, S., Gleeson, D., Jordan, K., Furey, A., O'Sullivan, K. and O'Brien, B. (2013). Strategy for reduction of Trichloromethane residue levels in farm bulk milk. *Journal of Dairy Research*, **80** 184-189.
Power, C., Danaher, M., Sayers, R., O'Brien, B., Clancy, C., Furey, A. and Jordan, K. (2013). Investigation of the migration of triclabendazole residues to milk products manufactured from bovine milk and stability therein, following lactating cow treatment. *Journal of Dairy Science*, **96** 6223-6332.

Popular publications:

McParland, S., McCarthy, J. and O'Brien, B. (2013). Animal and herd factors associated with somatic cell count of Irish Holstein-Friesians. In: Proceedings of Agricultural Research Forum, Tullamore Court Hotel, 12-Mar-2013, page 97.
Power, C., Danaher, M., Sayers, R., O'Brien, B., Whelan, M., Furey, A.and Jordan, K. (2012). Investigation of the persistence of Rafoxanide residues in bovine milk and fate during processing. Euroresidue VII Conference, The Netherlands.
O'Brien, B., Gleeson, D., Jordan, K. and S. Ryan. (2012). Control of trichloromethane (TCM) residues in milk. Poster presented at 2012 IDF World Dairy Summit, Capetown.

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