Summary

The dairy industry provides food products that promote health and well-being.

This industry helps to sustain rural communities and plays a vital role in land stewardship.

One of its key challenges is to expand production to meet demand from the growing world population and increasingly affluent societies.

To meet those goals, global research is focusing on the major production components – genetics, management and nutrition.

Their biggest challenge is to develop new technologies which will simultaneously minimise environmental impact and equally, prove to be economic.

Keywords: dairy, productivity, sustainability, genetics, management, nutrition, environment

Glossary

Freemartin: An infertile female mammal which has masculinized behaviour and non-functioning ovaries.

Nulliparous: A female who has never given birth to a viable, or live, infant.
Chemostatic mechanism: Blood levels of specific metabolites rise, sending a signal that causes the animal's appetite to be depressed.

Cholecystokinin: A peptide hormone of the gastrointestinal system responsible for stimulating the digestion of fat and protein.

Enteric fermentation: A digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal.

Sustainability: A sustainable dairy industry is one that is vibrant and enables people, environment and business to thrive.

The dairy sector's challenge

Global demand for dairy products is forecast to increase, particularly in the developing world, where total consumption of milk is estimated to increase by 3.3% per year to 2020 (1).

Furthermore, the trend is likely to continue as the global population is forecast to expand by nearly 30% to nine billion by 2050, which will pose substantial challenges to our ability to produce sufficient food in a resource-constrained world.

These challenges include minimising the environmental impacts of climate policy and climate change on agricultural production and of that production on climate.

Moreover, there is the need to overcome the economic difficulties of changing demands from civil society and from retailers.

Recently, there has been increasing recognition of these challenges and the need to act on them. There is considerable on-going work aimed at identifying the current level of impact of the dairy industry and how this might be improved.

In response, the Global Dairy Agenda for Action on Climate Change was launched in September 2009. Similarly, the Dairy Supply Chain Forum took the lead in the UK livestock sector by launching the Milk Roadmap in 2008, an evolving document which aims to reduce the environmental impact of the dairy industry.

However, what is noticeable about the majority of industry led initiatives to date, is that they tend to focus on single issues, particularly environmental ones, rather than the broader issue of the viability of the industry.

Emphasis has been placed on compliance and incremental improvement, rather than making a forward looking assessment of the industry as a whole.

This led us to work with the dairy industry and key stakeholders and establish Dairy 2020, a unique initiative within Europe, which takes a holistic approach to improving sustainability. Currently, there is no sense of a coherent future vision for the industry which is then often forced into a reactive position on critical issues.

There is a real need for the dairy industry to articulate why it is such an important industry in the UK and what positive impacts a thriving, industry could have on the country's economy, health and landscape.

The ultimate aim is for the Dairy 2020 project and our industry to be able to answer the question: "What does a sustainable dairy industry look like, and what contribution can it make to maintaining the ecosystem?"

The project has brought stakeholders in the dairy sector together to form a common understanding of what has to happen for it to be a successful industry in the future.

A final report has been published in spring 2012 which aims to create a strong sense of momentum and focus and develop tangible short, medium and long-term collaborative actions. The report includes recognition that we need to minimise the environmental impact of dairying, focus on stewarding nature and improving animal welfare.

One of the most immediate challenges is that the EU milk quota regime ends in 2015. Introduced in 1984, these quotas aimed to bring stability to the sector by putting an effective limit on annual milk production.

Some EU states are actively gearing up for massive expansion by 2020. For example, The Republic of Ireland is planning to increase total production by 50% or 2.5bn litres, while UK production could rise from the current 13.3bn litres to 15bn litres per year (2).

The UK dairy sector must meet this production challenge, against a backdrop of legislation which continues to reinforce the necessity to measurably reduce the environmental impact of all food production systems with improvements to animal welfare.

The potential to increase production efficiency is clearly demonstrated by progress in the world's leading dairy industries, with dramatic improvements in productivity during previous decades (Table 1).

These data highlight the improvements achieved in the US dairy industry since World War II, where a 61% increase in milk production has been achieved with a 64% lower dairy cow population.

This has contributed towards a dramatic increase in the efficiency of energy use – only 33% of energy consumed is used to maintain cows at present levels of production, compared with 69% for cows in 1944.

Furthermore, producing a given volume of milk today requires only 10% of the land area required in 1944, while the carbon footprint per unit of milk produced is only 37% of that 63 years earlier.

Similar strides have been achieved in the UK dairy industry, with the forecast for the next decade being for continued improvements in yield per cow to reach a total milk supply of 15bn litres from a similarly-sized national dairy herd to that of today (Table 2). This can best be achieved through improvements in the major production components – genetics, management and nutrition.

Genetics Innovations currently in progress are changing the way that geneticists undertake breed improvement, although improvements through genetics are likely to take longer than are those by either management or nutrition.

Genetic indices – many countries are now including more health and fertility traits in bull selection indices in an attempt to redress the problem of poor survival (5). The UK has introduced both a fertility index and a lifespan index based on daughter performance (6). Levels of herd fertility are more quickly influenced by management changes than breeding, but improvements through breeding are permanent and cumulative from one generation to the next.

Genomic selection (GS) – the most dramatic recent changes have come from GS which is significantly speeding up the rate of progress in global dairy cattle breeding. GS uses a very large number of DNA markers – currently in the range of 50,000 to 800,000 for most species - that have been derived from the reference cattle genome sequence (7).

In dairy cattle, GS allows prediction of the genetic merit of young animals – long before bulls will have daughter records available – from statistical associations of these DNA markers with trait measurements on past generations, referred to as the 'training' data.

This technology is now being widely applied and has reduced generation intervals in dairy cattle from over five years to under two, thereby increasing the annual rate of progress by about 60%.

GS technology is advancing so rapidly that within the foreseeable future it should be possible to sequence the entire genome of selected individual animals. For example, the determination of which genotypes may be associated with calf mortality at parturition offers the possibility of future genetic selection, of both bulls and breeding animals, against this adverse and wasteful trait.

Management UK dairying has predominantly focused on adult cow management while the importance of the herd's youngstock has tended to be ignored, a trend reflected in recent findings that almost 20% of all heifer calves born fail to calve for the first time (8). Table 3 identifies these losses and the factors responsible.

The adoption of some of the following basic management procedures together with the implementation of the latest advances in technology can play an important role in helping farmers to reduce these losses.

Sexed semen – technological advances in processing and storing sexed semen, since its introduction in 1997, have resulted in claims that sexed semen now produces similar conception rates to conventional semen.

Sexed semen could provide one method to help tackle the large wastage of calves around birth by delivering easier calving of female calves as well as reducing the large number of undesirable pure dairy bred male calves.

Colostrum – colostrum is essential for calves, providing nutrition (high levels of fat and lactose) and immunity (antibodies), but quality can vary considerably. Colostrometers – hydrometers that measure the specific gravity of colostrum – provide farmers with a rapid indication of its quality prior to feeding new born calves.

Weigh scales – measuring and monitoring growth rates are seldom practiced on dairy farms, however technological advances in portable weigh platforms have made recording live weight a feasible reality for every farmer.

The latest models combine simplicity with accuracy and convenience, and enable farmers to ensure calves achieve the industry- recommended growth rates of 0.7kg per day for heifers from birth to calving.

Linear trait classification scores – many of these measurements for cattle conformation (for example body, legs and feet, udder, teats) have medium to high genetic correlations with longevity and have been incorporated into breeding indexes (10, 11), however classification normally takes place during first lactation.

Frame classification scores in the first lactation have been shown to be strongly related to several size measurements of heifers when juveniles – consequently measurements of skeletal size, for example height and crown-rump length, at birth could assist in selecting the best heifers for breeding (9).

Heat detection – failure to detect heat (oestrous) is a major problem among today’s higher producing cows. Monitors are constantly evolving and their accuracy improving, for example detecting 3D movement via neck or ankle collars, and allowing wireless data downloads with a range of up to 150 m are now available.

Mastitis – a common condition in dairy herds, mastitis results in significant production and economic losses and is a major reason for culling cows. Early detection is vital and technology has been developing to facilitate early identification based on increased milk conductivity due to changes in cation-anion balance arising from the mastitic infection. Similarly, work is continuing to develop a vaccine against the major mastitis-causing organisms such as Escherichia coli and Staphylococcus aureus.

Lameness scoring – lameness is a major factor contributing to early culling. Cow lameness has multi- factorial causes, including poorly- designed housing and nutritionally- imbalanced rations. Initiatives such as the DairyCo Healthy Feet Programme target identification of specific problems causing lameness. Introducing longevity ‘type’ traits into breeding plans will contribute to reducing the incidence and extent of lameness on farms. In addition, some manufacturers have developed automatic lameness detectors which identify anomalies in cow walk patterns as an early indicator of the condition which enable treatment in a more prophylactic manner.

Nutrition Rationing animals accurately to meet required targets is essential to ensure the industry remains both viable and efficient. Considerable research effort has been directed at developing feeding systems to improve the feeding of modern animal types.

Youngstock – Nutrition of youngstock is less advanced in the UK than for adult dairy cows. Genetic selection has produced animals that grow progressively faster – so we need to feed calves in a way to maximise continually their growth rate potential and achieve the targeted two year age at first calving. Traditional UK standard practice has been to feed milk at 10% of the calf’s bodyweight to produce a healthy animal, however this restricts growth rate at the time of highest potential feed conversion efficiency in its life.

Colostrum management is a vital basic and we are continually urging producers to implement the ‘4Q’s’, or golden rules, when it comes to feeding – quality, quantity, quickly and quietly.

Technological advances in both milk replacers and feeding equipment make it possible to grow today’s modern dairy heifer at accelerated rates.

We launched a 26% protein and 16% fat milk replacer developed specifically for fast frame growth. For optimum intakes, computerised feeding systems allow calves to be fed high volumes of milk, little and often throughout the day. This system also monitors the volume drunk and drinking speed provides farmers with early warning of health issues.

Adult cows – nutritionists have a limited number of feed ingredients and energy sources available to help them meet the challenge of increasing individual cow productivity. Improvements in productivity must be achieved without negative effects on cow fertility, health and welfare.

In the first instance we have seen diets change dramatically in the UK as systems have gradually moved away from extensive forms of dairy production. Consequently the proportional contribution of grazed forage to cow diets has decreased.

Cow dry matter intake is limited by the rumen size and regulation by chemostatic mechanisms, including ‘type’ of nutrient metabolised in the liver (propionate vs acetate) and the effects of particular nutrients on satiety factors such as cholecystokinin (12). More intensive, cereal-based diets enable cows to consume higher levels of energy than through grass-based systems, facilitating greater production per cow, or allowing the cow to more closely fulfil her genetic potential.

However, we must not lose sight of the important and essential contribution home-grown forage will continue to make to the nutritional requirements of the herd.

Current feed systems (eg Feed into Milk; Thomas 2004) (13) enable ration formulation for cows at given levels of production.

However, a major challenge for animal nutritionists is to develop computer feed programs which facilitate response prediction to energy and nutrients, thereby improving rationing accuracy, feed efficiency and economic returns, based on an established marginal response to additional feed.

Attempts to predict responses to energy supplementation have been reported with some success (14).

Increasing output Increasing production invariably involves supplying additional feed to the cow, usually as more digestible, more efficiently-utilised feed sources.

In practice, increasing energy supply can be achieved by increasing the proportion of concentrate feed in the diet, for example wheat and maize.

However, this is not without its problems and relying too heavily on starch-rich feed sources can lead to problems such as acidosis – low rumen pH, and laminitis.

Using fat supplements as an energy source is one method of helping counteract the twin requirements of increasing production while maintaining or improving cow health. Fat has the highest gross energy concentration of any nutrient but simply adding it to a ration can cause major upset and reduce rumen function, by for example decreasing fibre digestibility (15).

Furthermore, according to the biohydrogenation theory of milk fat depression, the addition of unsaturated oil to rations can lead to the development of particular trans-fatty acids which are detrimental to milk fat production (16).

The potential negative effects of adding fats and oils to diets led Volac to launch Megalac rumen-protected fat, based on the calcium salt technology developed by Dr Don Palmquist at Ohio State University, USA. Farmers are now able to add fat to their rations ‘safely’ and improve production efficiency, cow fertility and animal health (e.g. reducing the acid load in the rumen and the consequent development of laminitis).

Fertility Poor fertility in UK dairy herds is another major issue. Conception rate to first service has fallen to below 40% (17), and is influenced by a number of factors, energy supply being one of the most critical.

Quality of ovulated eggs can be measurably improved by supplementing dairy diets with specific rumen-protected fat sources, which also increases progesterone production, the essential pregnancy hormone (18, 19). Implementation of

new technologies to more accurately predict oestrous (heat) could help improving pregnancy rates.

Environment Improving production efficiency is a vital component in reducing the dairy sector's environmental impact. It is estimated anthropogenic emissions from processing and transportation account for 2.7% (±26%) of the total emissions of global milk production (FAO 2010) (20).

Methane – methane is estimated to account for between 30% and 50% of total greenhouse gas emitted from the livestock sector, with approximately 80% coming from enteric production in the rumen (21).

As well as the negative environmental implications, methane represents a considerable loss of energy to ruminants, ranging from less than 2% to over 10% of gross energy intake.

Methane is primarily produced as a by-product of anaerobic fermentation in the rumen by micro-organisms, facilitating the utilisation and digestion of poor quality, high cellulose forages.

However, grazing and high forage production systems inherently produce more methane than high concentrate systems, providing scope to manipulate diet composition to reduce enteric methane production.

Various methodologies have been studied to reduce ruminal methane production, including dietary addition of unsaturated fatty acids to act as hydrogen sinks (22), medium-chain fatty acids as microbial inhibitors (23), and garlic to directly inhibit methanogenic bacteria or the metabolic pathways of methane synthesis (24).

Efficiency Improving production and fertility per animal can make a major contribution to gross efficiency of dairy herds. Yan et al. (25) concluded that selection of cows capable of high levels of milk production and energy utilization efficiency offers an effective approach to reducing methane emissions from lactating dairy cows.

Producing 1M litres of milk from cows yielding 9,000 litres per cow per year would reduce methane production to approximately half that of cows yielding only 6,000 litres per year (26).

Herd replacements contribute up to 27% of the methane and 15% of the ammonia produced by dairy cows in the UK, but substantial reductions in emissions of these pollutants can be achieved by improvements in fertility and cow longevity (26).

Similarly, increasing cow longevity from three to 3.6 lactations would reduce lifetime greenhouse gas footprint (kg CO2e/litre milk) by 4.4% (27).

Conclusions

Increasing output, as achieved on dairy farms over past decades, must continue if we are to feed the rapidly increasing world population and at the same time achieve a sustainable sector.

This will require greater adoption of technological developments to increase productive efficiency – milk output per unit of resource input; and at the same time reduce environmental impact.

We have already witnessed huge improvements in global production efficiency; a given volume of milk requires just 10% of the land area

while the carbon foot print of milk is only 37% that of 60 years ago. To maintain this and to improve those levels of efficiency, the dairy sector is looking forward to the introduction of a number of new technologies.

For example genomic selection is advancing genetic progress by 60% annually, a miscellany of tools from sexed semen and heat detectors to simple weigh scales will bring significant improvements to efficiency, while on-going developments to improve longevity will increase productive efficiency and reduce lifetime dairy cow carbon emissions.

A significant proportion of the improvements in productive efficiency has been achieved through increased use of cereals and protein crops, which itself raises questions about the role of these feeds in animal production versus competing needs for human consumption.

Continued take up by dairy farmers will be dependent on whether or not investment in each development can prove to be cost effective, both for the short and long term, and that it will fit within the sector's complex legislative framework.

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Figures

Table 1: US dairy industry - comparative production 1944 v 2007

	1944	2007
Cows (millions)	25.6	9.3
Milk yield (billion litres)	53.2	86.4
Average milk yield (litres/day)	6.8	29.5
Proportion of energy required for maintenance (%)	69	33

(Capper *et al* 2009) (3)

Figure 1.

Table 2: The UK dairy sector – past, present and future

	1960	2010	2020
Cows (millions)	3.2	1.85	1.85
Milk yield (litres/cow/year)	3,344	7,217	8,218
UK production (billion litres)	10.7	13.3	15.0

(Brigstocke 2004; Kite Consulting 2011 Vision for 2020) (4, 2)

Figure 2.

Table 3: Summary of losses of potential replacement heifers from the time of maternal insemination until their own first calving

Stage of life	% of Starting number	Lost*	Reason
Pre-natal losses			
Insemination of dam	100		
Fertilisation of oocyte	90	10%	Fertilisation failure, wrong time of AI
Pregnant at 24 days post AI	54	40%	Early embryo mortality
Pregnant at 60 days post AI	43	20%	Late embryo mortality
Pregnant in late gestation	41	5%	Abortion
Post-natal losses			
Calf alive at 24 h postpartum	38	8%	Perinatal mortality
Live heifer calf	19	50%	Unwanted male calves
Alive at one month	18	5%	Neonatal mortality & freemartins
Alive at 15 months	16	7%	Calf & juvenile mortality
Pregnant as nulliparous heifer	15	3%	Conception failure
Pregnant in late gestation	15	3%	Culled following embryo loss or abortion
Heifer starts first lactation	14	2%	Maternal death at calving

(Wathes *et al* 2008) (9)

*Values indicate the proportions of the total lost during each period- prenatal and post-natal.

Figure 3.

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Comments