CHAPTER 1

Sustainability and One Health

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Learning objectives

- Understand future demands for food production and the need for sustainability.
- Appreciate the global impact of bovine production.
- Be aware of the opportunities for mitigation.
- Understand the environmental impacts and public perception.
- Appreciate the role of the veterinarian/animal scientist and future developments.

Introduction

The sustainability of global bovine production systems is currently one of the most highly debated issues relating to food production. Ruminant livestock provide high-quality animal-source foods in conjunction with a myriad of associated economic and social benefits to communities worldwide. Nonetheless, the question is often raised as to whether the consumption of milk and meat is inherently unsustainable.

Sustainability was defined within the Brundtland Report (United Nations World Commission on Environment & Development, 1987) as: *'meeting the needs of the present without compromising the ability of future generations to meet their own needs'*, and this remains the most commonly used definition, implying the need to use resources at rates that do not exceed the earth's capacity to replenish them, while ensuring human food security. 870 million people are currently considered to be food-insecure on a global basis (Food & Agriculture Organisation of the United Nations, 2012), so global food production could be argued to be unsustainable as per the first half of the definition.

Nonetheless, a sustainable food system is not simply dependent upon producing sufficient food but upon delivering and marketing food through an efficient infrastructure with minimal waste. The political and logistical challenges associated with food provision to currently food-insecure populations are beyond the scale of this chapter, so discussion will be confined to the three pillars of sustainability (i.e. economic viability, social responsibility and particularly environmental stewardship), as these relate to bovine production systems.

Within any production system, a balance must exist between environmental stewardship, economic viability and social responsibility; if one of these factors is out of alignment, the system cannot achieve long-term sustainability. For example, the use of hormone implants to improve productivity within US beef production has positive economic and environmental effects (Capper & Hayes, 2012), yet such technologies are not registered for use within the European Union and, as such, are socially unacceptable (Lusk *et al.*, 2003). No 'magic bullet' or suite of production practices exists to achieve global sustainability; individual production systems must be tailored to the resources, climate and culture indigenous to that region and to potential export markets. However, there is no doubt that prevailing global consumer and policy-maker concerns regarding the environmental sustainability of bovine production will have considerable effects on future production systems.

The global population is predicted to plateau at over 9.5 billion people in the year 2050 (Food & Agriculture Organisation of the United Nations, 2009) with disproportionate increases in population growth in the developing world. Concurrent increases in the *per capita* income within China, India and Africa over this time period will result in considerable increases in animal-source food consumption within currently impoverished nations and a projected 70% increase in global food requirements (Food & Agriculture Organisation of the United Nations, 2009; Masuda & Goldsmith, 2010).

The challenge facing global bovine production is to supply the growing population with sufficient economically affordable

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milk and meat products to maintain dietary choice and human health while minimising environmental impact through reductions in both resource use and waste output. This challenge has myriad implications at the regional level, many of which are dependent on the current state of agricultural research and technology adoption. Despite the highly developed nature of the UK agricultural production system, Leaver (2009) notes that significant investment in research and development, and a greater collaboration between agricultural practice and science, are required in order to meet the rising demand for food in the UK (predicted to increase by 25% over the next 50 years) and to remain competitive on the global market.

What is the global impact of bovine production?

Discussion of animal agriculture's environmental impact is often restricted to greenhouse gas (GHG) emissions. Under the Climate Change Act of 2008, the UK government made a legally binding commitment to reduce GHG emissions by 80% by the year 2050, including a 11% reduction in GHG emissions (based on 2008 emissions) from agriculture by 2020 (HM Government, 2008), underlining the significant political concerns relating to this issue. However, resource scarcity (specifically water, land, inorganic fertilisers and fossil fuels) may be argued to have a greater immediate effect upon food production than climate change. Dairy and beef production also have a variety of direct environmental impacts (including positive and negative effects upon water and air quality, nutrient leaching, soil erosion and biodiversity) that should be included in environmental assessments. Nonetheless, the majority of studies to date have concentrated on GHG as the sole arbiter of environmental impact, so therefore GHG will be assumed to be a valid proxy for environmental effects in the following discussion, unless otherwise stated.

Global GHG emissions from agriculture were estimated by Bellarby *et al*. (2008) to account for between 17% and 32% of all human-induced emissions, with a recent report by the FAO (Food & Agriculture Organisation of the United Nations, 2006), concluding that animal agriculture contributes 18% of GHG emissions. In conjunction with estimates citing animal agriculture's contribution at up to 51% (Goodland & Anhang, 2009), these data have been eagerly adopted by activist groups as evidence for the benefits of a vegetarian or vegan lifestyle (Environmental Working Group, 2011). Due to methodological flaws, the 18% figure cited by the FAO is considered to be an overestimate (Pitesky *et al*., 2009). Nonetheless, ruminant production systems make a significant contribution to total GHG emissions and resource use, due to having relatively less efficient feed conversion than their monogastric cohorts.

Dairy production accounts for approximately 2.7% of worldwide GHG emissions, with average emissions of 2.4 kg CO_2-eq/kg FPCM (fat and protein-corrected milk) at the farm gate (Food & Agriculture Organisation of the United Nations, 2010). Nonetheless, significant regional variation exists, with emissions ranging from 1.3 CO_2-eq/kg FPCM in North America to 7.5 kg CO_2-eq/kg FPCM in sub-Saharan Africa. Plotting average FPC milk yield against carbon footprint reveals a negative correlation - as production intensity and milk yield decrease with a regional shift from the developed to the developing world, GHG emissions increase (Figure 1.1).

Similar effects of productivity upon GHG emissions would be predicted for global beef production, yet are not borne out by comparisons among studies (Figure 1.2). These exhibit considerable methodological variation, and show that intensive systems have GHG emissions per kg beef ranging from 9.9–36.4 kg CO_2-eq, compared with extensive systems at 12.0–44.0 kg CO_2-eq/kg beef (Capper, 2011b; Cederberg *et al*., 2011; Ogino *et al*., 2004; Peters *et al*., 2010).

Within both dairy and beef production, the environmental mitigation effect of improved productivity is conferred by the 'dilution of maintenance' concept, as shown in Figure 1.3 (Capper, 2011a; Capper *et al*., 2008).

Every animal in the dairy or beef herd has a daily maintenance nutrient requirement that can be considered as a proxy for resource use and GHG emissions. As productivity (milk yield, meat yield or growth rate) increases, the proportion of daily energy allocated to maintenance decreases and the maintenance requirement of the total animal population decreases. This is exemplified by comparing the US dairy industries in 1944 and 2007: a four-fold increase in milk yield per cow over this time period reduced the national dairy herd from 25.6 million to 9.2 million cattle, with a concurrent 59% increase in milk production (53 billion kg in 1944 vs. 84 billion kg in 2007). This reduced feed use by 77%, land use by 90%, water use by 65% and conferred a 63% decrease in GHG emissions per kg of milk (Capper *et al*., 2009). Similarly, if growth rate is increased in beef cattle, the population maintenance requirement is reduced because cattle take fewer days to reach slaughter weight. Considerable reductions in feed (19%), land (33%), water (12%) and GHG emissions (16%) were demonstrated by productivity improvements within the US cattle industry between 1977 and 2007 (Capper, 2011a). In this instance, environmental impact was reduced by an interaction between greater slaughter weights (607 kg *vs*. 468 kg) and faster average growth rates (1.18 kg/d vs. 0.72 kg/d) in 2007 compared with 1977 (Figure 1.3).

It is clear that improving system productivity and efficiency has a significant effect upon environmental sustainability. The aforementioned regional comparisons could lead to the conclusion that, for example, all regions should adopt confined

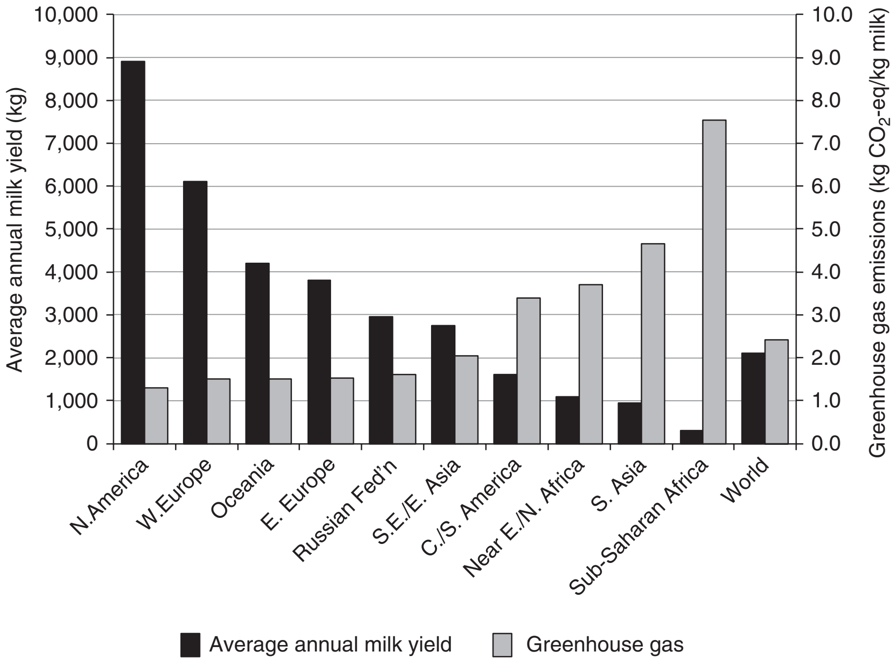

Figure 1.1 Relationship between average annual milk yield and greenhouse gas emissions per unit of milk on a regional and global basis.

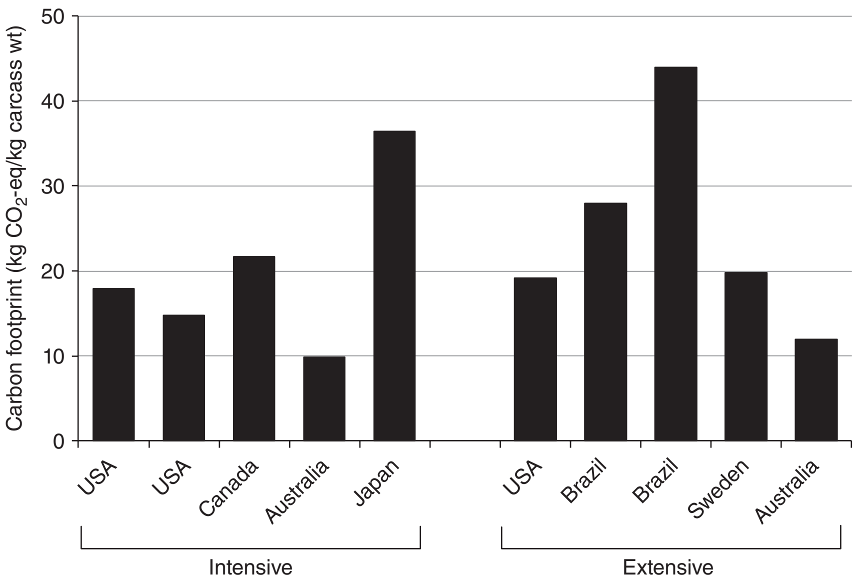

Figure 1.2 Regional and production system (intensive vs. extensive) variation in greenhouse gas emissions per unit of beef.

feeding operations such as those commonly practised in North America, in order to mitigate environmental impact. However, the three-faceted nature of sustainability must be considered; GHG emissions from dairy cattle in sub-Saharan Africa may be considerably higher than those in Europe. However, the nutritional and economic value gained from animal production, in addition to the social status of livestock ownership in developing countries, means that environmental impact cannot and should not be the sole consideration.

However, making the most efficient use of available resources has a two-fold advantage to the producer – efficient use of resources reduces environmental impact and reduces the economic costs of production (Capper & Hayes, 2012), thus contributing to economic viability.

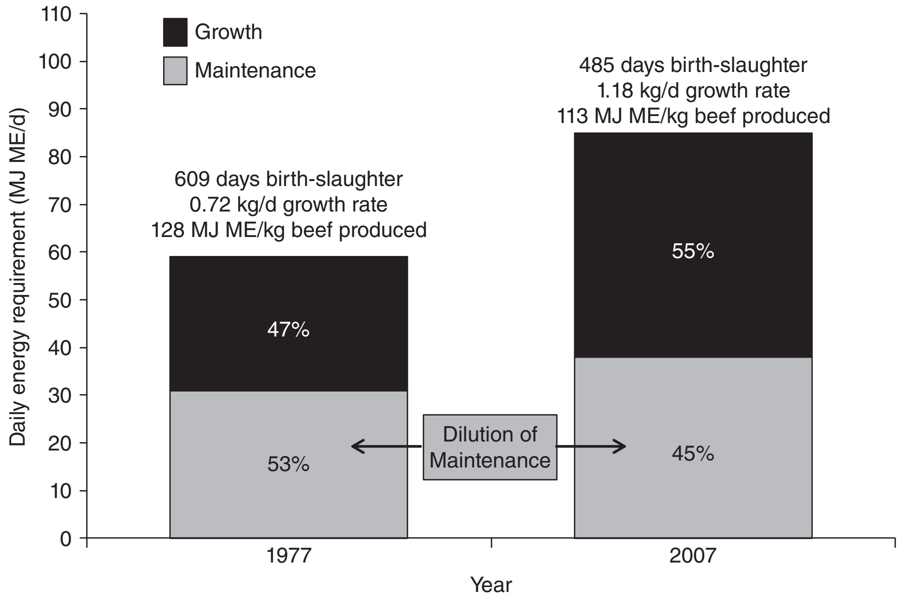

Figure 1.3 An example of the dilution of maintenance effect – comparing US beef production in 1977 and 2007.

What are the opportunities for mitigation?

Improved efficiency is inherently tied to a reduction in waste and losses throughout the system. This may be achieved through management practices that reduce specific environmental impacts, e.g. soil testing to assess fertiliser requirements, slurry injection to reduce nutrient leaching or recycling water for parlour sanitation (Figure 1.4).

However, whole-system approaches may have a greater overall mitigation effect. If a dairy or beef system working at optimal efficiency within every sub-system could potentially produce a set quantity of milk or meat based on animal genetic merit, every productivity loss within the system will reduce the potential yield and increase the environmental impact per unit of food produced. The potential losses from dairy and beef systems that will impact environmental sustainability are presented in Figure 1.5.

Productivity measures such as milk yield (dairy) and growth rate (beef) arguably have the most significant effect upon environmental sustainability, yet other metrics must also be

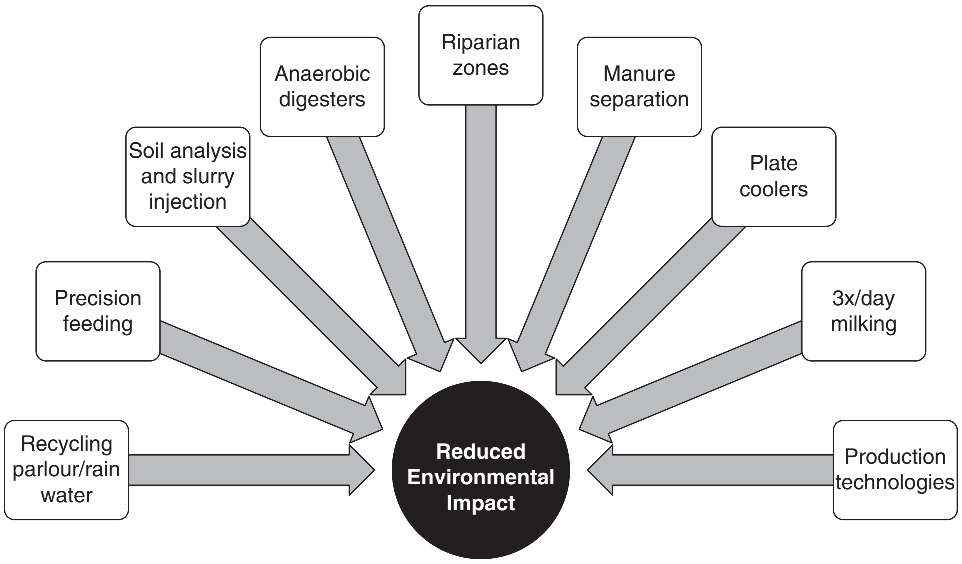

Figure 1.4 Specific management practices targeted to reduce the environmental impact of ruminant production.

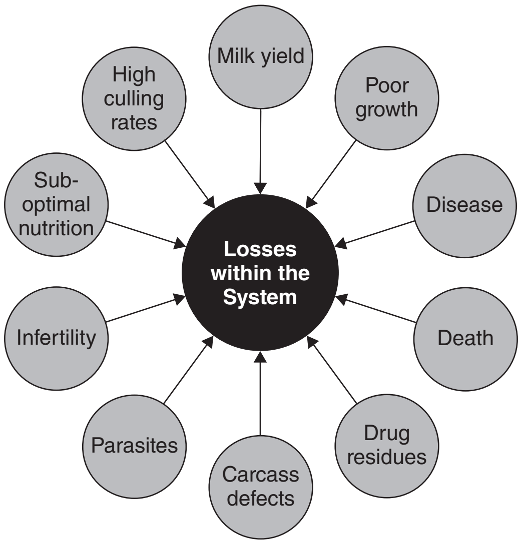

Figure 1.5 Losses within ruminant production systems that potentially increase environmental impact.

considered. To date, the environmental effects of less tangible productivity losses within dairy and beef systems (e.g. fertility, morbidity and growth of heifer replacements) have yet to be quantified.

Across dairy and beef industries, mature cow body weight has often increased concurrently with productivity gains, so daily resource use and GHG emissions per animal have increased (Capper, 2011a; Capper *et al.*, 2008). This may lead to future legislative complications if environmental assessments are based upon the number of livestock units per operation, without consideration of productivity.

In an evaluation of the environmental impact of cheese production from Jersey and Holstein milk, Capper & Cady (2012) demonstrated that land use, water use and GHG emissions were reduced by 32%, 11% and 20% respectively by the use of Jersey cattle. In this instance, environmental savings were conferred by the interaction between an increase in milk fat and protein content, combined with decreases in body weight and milk yield for Jersey cattle. Nonetheless, when breed-specific traits were examined in isolation, the difference in body weight between Jersey (454 kg) and Holstein (680 kg) cattle led to a 74% reduction in population body mass (and thus a reduced population maintenance requirement), despite a 9% increase in the total number of cattle required to produce an equivalent amount of cheese. Within this study, body weight was the most influential factor affecting environmental impact, with milk composition and milk yield following closely behind, yet with little effect of age at first calving, culling rate or calving interval.

These results were echoed by Bell *et al.* (2011), who reported that changing energy-corrected milk (ECM) yield (highly correlated with cheese yield) by one standard deviation conferred a 14.1% decrease in the carbon footprint per unit of ECM compared with feed efficiency, calving interval or culling rate (6.0%, 0.40% and 0.14% decreases, respectively).

Significant interest exists among beef producers in selecting cattle for improved feed efficiency, either as an improvement in residual feed intake (RFI; i.e. reduced feed consumption requirement to support maintenance and production compared with the predicted or average quantity), or through cows that have a lesser body weight, yet still produce calves that reach target weights for weaning and finishing. The development of estimated breeding values (EBVs) for RFI is relatively new, yet appears to show promise as a strategy by which producers may improve environmental impact.

Steers selected for high efficiency (low RFI) consumed less feed over the finishing period compared with low-efficiency cohorts in a large-scale feedlot study by Herd *et al.* (2009), exhibiting a greater dressing percentage and equal finishing weight at slaughter. Furthermore, Hegarty *et al.* (2007) reported that Angus steers showed considerable variation in methane emissions relative to intake, yet those selected for a lower RFI had reduced emissions consistent with reduced dry matter intake (DMI).

If productivity may be maintained on a reduced DMI, as per the aforementioned Holstein vs. Jersey example, resource use and GHG emissions would also be predicted to decrease per unit of output. For example, if mature cow body weight were reduced from 703 kg to 486 kg, while maintaining the final carcass weight of the offspring, GHG emissions per unit of beef would decline by 13% (Figure 1.6).

A negative trade-off exists, whereby selection for increased productivity within dairy cattle is generally considered to have contributed to declining fertility rates. Garnsworthy (2004) demonstrated that restoring fertility levels to those seen in UK dairy cattle c. 1995 reduced methane emissions per unit of milk compared with current fertility levels, and achieving ideal fertility reduced GHG emissions still further through a reduction in the number of heifer replacements required within the herd.

Fertility is arguably the major factor by which global beef producers (specifically seed stock and cow-calf producers) could also mitigate the environmental impact of beef production. Within beef production, conflict may also exist between selection for paternal traits (e.g. growth, carcass weight or frame size) and maternal traits (e.g. fertility, milk yield) under the nutritional limitations of pasture-based systems (Renquist *et al.*, 2006). Within the USA, 89% of cows bear a live calf each year (USDA, 2009), and this number declines to between 50–60% in the extensive systems characteristic of Brazil, Argentina and Chile. Given that the cow-calf operation contributes up to 80% of GHG emissions per unit of beef (Beauchemin *et al.*, 2010), and that productivity improvements post-calving cannot

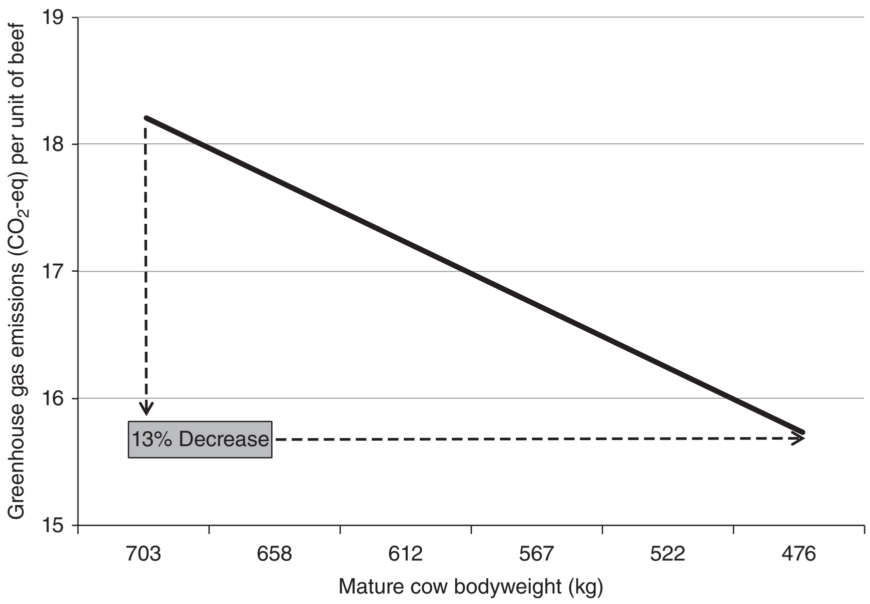

Figure 1.6 The effect of reducing mature beef cow body weight upon greenhouse gas emissions per unit of beef.

compensate for the resource use and GHG emissions associated with maintaining a non-productive cow, management practices and technologies that improve pregnancy rate offer significant opportunities.

Environmental impact and public perception

It is tempting to try to identify so-called 'silver bullets' that will instantly mitigate the environmental impact of dairy or beef production. Such interventions are often targeted by marketing campaigns or media as providing a simple solution, yet they may result in significant negative trade-offs. One example would be the installation of methane digesters which, although effective at reducing total GHG emissions from dairy production, are often economically prohibitive and require significant skilled labour to operate correctly (Chianese *et al.*, 2009). The supposition that transport of feed or fertilisers confers a far greater GHG burden upon grain-fed beef, compared with grass-finished systems, is often propounded in the media. However, recent studies show that GHG from transportation accounts for less than 1% of the carbon emissions associated with a unit of beef (Capper, 2011a; Capper, 2012), and that beef from cattle produced in wholly forage-fed systems is associated with considerable increases in land (80.8%), water (303%) and GHG emissions (70.4%), due to efficiency differences between systems.

In the USA and other developed regions, campaigns such as 'Meatless Mondays' or 'Meat Free Mondays' have emerged in recent years, as consumers increasingly perceive that animal protein consumption is environmentally or physically unhealthy. Scientific credence is lent to the campaign by papers evaluating the environmental impact of reducing meat consumption, with one such paper by researchers from Carnegie-Mellon University concluding that: '*Switching less than one day per week's worth of calories from red meat and dairy products to chicken, fish, eggs or a vegetable-based diet achieves more greenhouse gas reductions than buying all locally sourced food*' (Weber & Matthews, 2008).

Regardless of the underlying motivation for the Meatless Monday campaigns, the claims for a significant improvement in environmental impact appear to be over-exaggerated. To use the USA as an example, the US Environmental Protection Agency cites red meat and dairy production as contributing 2.1% of annual GHG emissions (US EPA, 2013). If we take the simplistic view that a one-day per week reduction in meat consumption would cut animal production by one-seventh, if every one of the USA's 316 million inhabitants adopted such a dietary change, the projected reduction in national GHG emissions would be equal to 0.30%. It is somewhat difficult to view a change that reduces national GHG emissions by less than one-third of one percent as having a meaningful environmental impact.

The claim that the world's nutrient requirements could be met simply using the grains currently fed to livestock is one of the most commonly heard arguments for vegetarianism or veganism and is often accompanied by a claim that it takes 10, 20 or even 30 kg of grain (Palmquist, 2011) to produce a kilogram of meat. Aside from the biological implausibility of the aforementioned numbers (corn only accounts for 7% of the total feed used to produce a kilo of beef in the USA), the implicit assumption is that the human population would be content to survive on a corn-based diet. Yet, when the additional land and resources required to grow other, lower-yielding crops (e.g.

salad leaves, asparagus and Brussels sprouts) to maintain dietary variety is included in the calculation, whole-scale conversion to vegetarianism appears to be a considerable challenge.

In an elegant comparison of resource use for various different diets, Fairlie (2010) notes that converting from the conventional omnivorous diet to a vegan system would reduce overall land use, yet the reduction is almost entirely confined to pasture land. The amount of land used for annual crops is increased in Fairlie's vegan scenario, due both to the lack of animal manures for fertiliser and to the need to provide fats and oils for energy within the human diet. Considerable quantities of pastureland are currently used to raise livestock, leading to the suggestion that the land could be far better employed to raise human food crops. However, only a small proportion of grazed pasturelands is suitable for food crop production, due to terrain, water or nutrient restrictions – indeed, 60% of farmed land in the UK is only suitable for pasture production (Pullar *et al.*, 2011).

The relatively low feed conversion efficiency of plant-based feedstuffs into animal proteins is likely to remain one of the biggest arguments against the omnivorous diet, yet is also one of livestock production's biggest selling points. Considerable quantities of by-products from the human feed and fibre industries are currently used within livestock diets – quantities which are often overlooked by governmental or organisational reports that cite grain-fed production as being unsustainable (Environmental Working Group, 2011; Foresight, 2011). When feed efficiency is quantified as a ratio of human-edible protein input to human-edible protein output, both dairy and grass-fed beef cattle produce a greater amount of human-edible food than they consume (due to the quantities of forage used within the diet), and lamb, swine and poultry have feed efficiency ratios between 1.1 and 2.6 kg human-edible protein input per kg of human-edible protein output (Wilkinson, 2011). Given the amino acid balance and protein quality of animal proteins compared with plant-based foods, this strengthens the rationale for maintaining omnivorous diets.

Role of the veterinarian/animal scientist and future developments

The veterinary and animal science communities have a significant role to play in helping to mitigate the environmental impact of ruminant production (Green *et al.*, 2011). Aforementioned productivity improvements that help to reduce resource use and GHG emissions can only be achieved through collaboration between producers, veterinarians, other allied industry and academia, in order to ensure that animals are bred, fed and cared for using management practices and technologies that will enable cattle to perform to their genetic potential.

Technologies such as ionophores, steroid implants, hormones and beta-agonists have a significant role to play in improving the environmental impact of ruminant production. Capper *et al.* (2008) demonstrated that use of recombinant bovine somatotropin reduced the GHG emissions from dairy production by 8.8%, while removing production-enhancing technology from US beef production was predicted by Capper & Hayes (2012) to increase resource use, to be equivalent to imposing an 8.2% economic tax on beef producers, and to increase global GHG emissions by 3.14 billion metric tonnes over time as a consequence of shifts in exports from countries with less-intensive production systems.

Despite considerable evaluation by national and global health agencies, and the prevailing opinion that no human health threats are presented by the use of such technologies, political and social agendas often oppose the approval or registration of these product within specific regions. Approval has recently been gained for the use of beta-agonists within Brazilian beef production systems and, as Brazil is a major beef producer, it will be interesting to see whether this sets a precedent for use of other technologies. The input of researchers, veterinarians and animal science professionals will be crucial within future debates, in order to ensure that science is not lost amongst public perception or political considerations.

When attempting to improve the sustainability of any system, it is crucial to note that, although productivity indices exist that are consistent across the spectrum, changes in management practice must be implemented with due consideration for the system resources in terms of labour, labour, economics, market and animal characteristics. No 'one-size-fits-all' solution exists yet, if all systems improve efficiency and productivity on a global scale, the challenge of meeting human food requirements for milk and meat products by the year 2050 becomes far more achievable.

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