



Conference on ‘Sustainable food consumption’

Improving the sustainability of global meat and milk production

Andrew M. Salter

Division of Nutritional Sciences, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, LE12 5RD, UK

Global demand for meat and dairy products has increased dramatically in recent decades and, through a combination of global population growth, increased lifespan and improved economic prosperity in the developing world will inevitably continue to increase. The predicted increases in livestock production will put a potentially unsustainable burden on global resources, including land for production of crops required for animal feed and fresh water. Furthermore, animal production itself is associated with greenhouse gas production, which may speed up global warming and thereby impact on our ability to produce food. There is, therefore, an urgent need to find methods to improve the sustainability of livestock production. This review will consider various options for improving the sustainability of livestock production with particular emphasis on finding ways to replace conventional crops as sources of animal feeds. Alternatives, such as currently underutilised crops (grown on a marginal land) and insects, reared on substrates not suitable for direct consumption by farm animals, represent possible solutions. Coupled with a moderation of excessive meat consumption in wealthier countries, such strategies may secure the long-term sustainability of meat and milk production and mitigate against the adverse health effects of excessive intake.

Meat: Milk: Livestock: Sustainability: Food security

When given the choice, most human subjects will include at least some meat and dairy produce in their diet. While a fully plant-based diet can provide all essential nutrients, this usually requires consumption of a relatively diverse combination of fruit and vegetables. In areas of the world where protein–energy malnutrition and micronutrient deficiency are prevalent, diets are normally low in animal products and reliant on a limited range of plant-derived foods. It is perhaps unsurprising that as countries achieve greater economic stability they aspire to a more Western diet, containing greater quantities of meat and dairy products.

Meat represents an energy-dense source of high-quality protein, and is enriched in micronutrients such as thiamine, niacin, vitamin B₁₂, calcium, iron, zinc, potassium and phosphorus⁽¹⁾. Milk and dairy products are also an important source of protein and make major contributions to intake of calcium, phosphorus, iron, vitamin A and riboflavin⁽²⁾. Overall, it may be argued that maintaining a certain level of global livestock production

and consumption of animal products has considerable potential to alleviate malnutrition and deliver economic advantages to a given population⁽³⁾. However, the excessive level of consumption seen in many of the world’s wealthiest countries not only places an unsustainable burden on the environment, but also impacts on susceptibility to a range of chronic diseases, including obesity, diabetes, CVD and certain cancers⁽⁴⁾. A major challenge over the coming decades will be ensuring that the nutritional benefits of consuming more meat and dairy products in countries with emerging economies is carefully balanced against the negative effects this may have on the environment and the incidence of chronic disease.

In general, as a country becomes wealthier, consumption of animal products increases. Until recently, the highest levels of meat production were associated with North America, Europe and Australasia⁽⁵⁾. However, as shown in Fig. 1a–c, the past 20 years have seen major changes in such production patterns. While the USA is still the major producer of beef, this has remained

Corresponding author: Professor A. M. Salter, email Andrew.Salter@nottingham.ac.uk

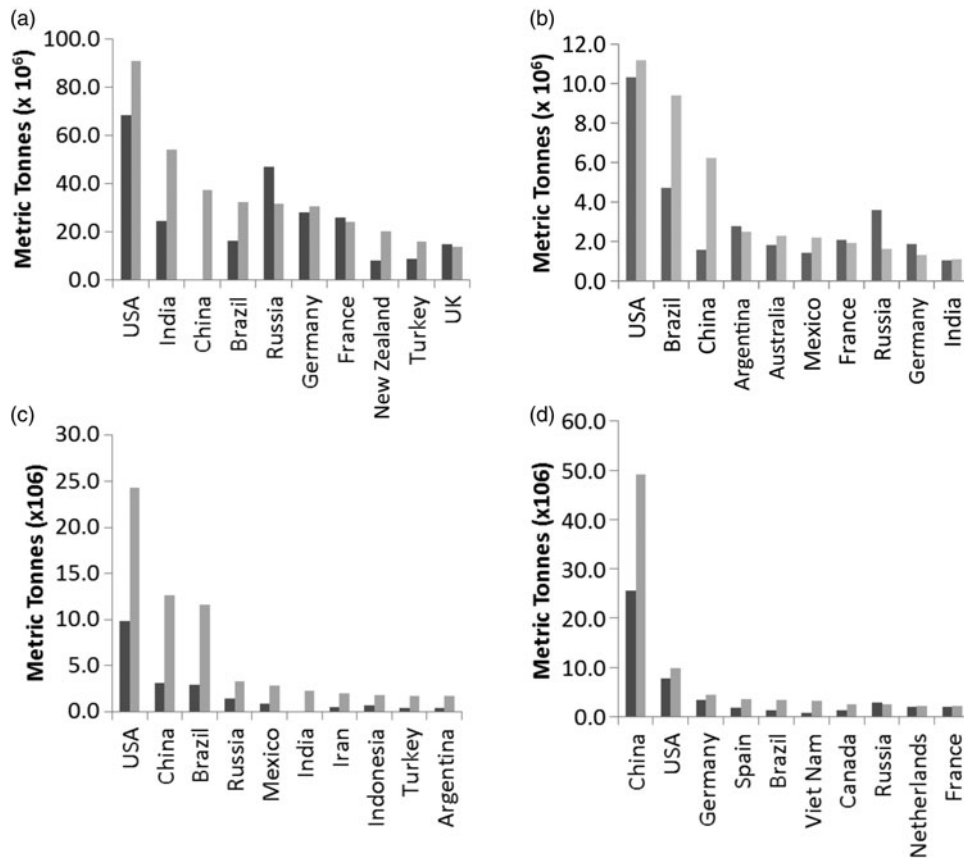


Fig. 1. Top ten countries producing (a) cow's milk, (b) beef, (c) chicken, (d) pork in 1992 (dark grey bars) and 2012 (light grey bars). Data from FAO⁽⁵⁾.

relative static over the past 20 years. By contrast, production in Brazil has almost doubled to levels approaching those in the USA. In China, while production of beef remains at about half that of the USA, this represents a tripling of the amount produce two decades ago. While China has dominated global pork production over several decades, this has further doubled in the past 20 years and is now responsible for 60 % of the world's pig production. Production of chicken has increased dramatically across the world and notably India, traditionally a very low consumer of meat products, is now one of the top ten world producers.

Most of this growth in global animal production has been driven by improving economic status of the countries involved. However, other factors are also predicted to impact on future trends. It is anticipated that the global population will increase from a current value of approximately 7 billion to about 9 billion by the year 2050⁽⁶⁾. Essentially all of this growth is likely to occur in the developing world where consumption of animal products is currently relatively low. For example, livestock product consumption in Kenya in 2005 represented 906.3 kJ/person per d (216.6 kcal/person per d) compared with 900 in the USA⁽⁴⁾. Improved nutrition, reduced infant mortality and reduction in infectious diseases are all likely to contribute to such increases in population growth. However, such factors are also likely to

contribute to increased lifespan, which in itself requires more food to feed an ageing population. If current trends continue then increased economic prosperity, increased population and extended lifespan will all contribute to increased demand for meat and milk. There is now serious concern over the impact of such increases in livestock production on land and water use and on the production of greenhouse gases which may directly contribute to global warming⁽⁶⁻⁸⁾.

Improved efficiency of farm animals

Historically, the increased demand for meat in North America, Western Europe and other industrialised parts of the world has been met by major advances in agricultural practice. Through selective breeding, precise nutritional strategies, changes in husbandry practices and improvements in animal health, marked improvements have been made in the efficiency of animal production. While considerable improvements have been achieved for all livestock species perhaps the most impressive changes have been achieved in poultry⁽⁹⁾. The impact of selective breeding was graphically illustrated by Zuidhof *et al.*⁽¹⁰⁾ who compared the growth characteristics of a broiler strain which had remained unselected from 1957 with a current day commercial strain. At



age 42 d the modern strain had over 400 % higher growth rate and 50 % reduction in feed conversion rate (g feed:g bodyweight) compared with the historic strain. Major improvements were also seen in body composition, with yield of the major breast muscle (per kg body weight) increasing by approximately 80 %. Similar improvements in feed conversion have also been achieved in pigs⁽¹¹⁾.

While dramatic improvements have been made in the efficiency of animal growth this has been achieved, particularly in monogastric animals, through the use of highly nutritious feed ingredients which often could be fed directly to human subjects. Inevitably, such animals will use energy derived from such feed for maintenance and exercise, leading to losses in human-edible energy. For ruminant animals the picture is more complicated due to their ability to graze on plant material not suitable for direct human consumption, frequently grown on land that would not support the production of conventional crops. However, in many parts of the world such diets are frequently supplemented with high-value crops such as wheat, soya and maize⁽¹²⁾. On a total feed intake basis, ruminant animals appear to be highly inefficient at converting energy and protein taken in, into human-edible energy and protein that can be consumed as meat from such animals. However, if this is recalculated as human-edible energy/protein consumed against that produced, then in animals which are largely grazed on pasture land, the figure improves substantially. Wilkinson⁽¹²⁾ demonstrated that the feed conversion ratio (feed intake per unit of fresh product) for production of beef ranged from 13.2 to 40 for energy, and 8.3 to 26.3 for protein, depending on the production system used. The highest values were seen in those animals fed predominantly on fresh/preserved forage. However, when the data were re-expressed in terms of the amount of human-edible feed consumed by the animal these figures reduced to 1.9–6.2 for energy and 0.92–3.0 for protein. These values compare relatively well to those estimated for production of pork (energy 6.3 and protein 2.6) and poultry (energy 3.3 and protein 2.3). It is of note that the pig and poultry values depend on the husbandry practices involved, with intensive housing inevitably improving efficiency compared with outdoor free-range production. Overall, it is clear that when using human-edible crops for feed, it can require anywhere between 3 and 6 MJ human-edible feed to produce 1 MJ energy in the form of meat. It is unsurprising that, against a background of increasing demand for food, the use of such natural resources has been called into question. This also has to be viewed against the impact of livestock farming on global warming. It has been estimated that agriculture accounts for up to 22 % of total greenhouse gas emissions of which 80 % is associated with livestock production^(13–15). This includes that associated with deforestation, on farm fossil fuel use, that associated animal manure and direct gas (particularly methane) production by the animal themselves. Considerable debate also surrounds the potential environmental impact of livestock production on water use^(16,17). While, it is clear that large variations exist

depending on the agricultural system to use to rear animals, against a background of climate change, this also represents an important consideration when predicting large increases in demand for meat and other animal products.

How do we mitigate against the potential negative impact of an almost inevitable increase in demand for animal products in the coming decades? The remainder of this review will focus on two specific areas of potential mitigation: (1) reducing the reliance of livestock production on human-edible crops and (2) reducing meat consumption within the developed world and minimising the predicted increase in demand for such products in the developing world.

Reducing the reliance of livestock production on human-edible crops

As briefly alluded to earlier, one of the major factors associated with our ability to continue to meet demand for animal products has been the success of conventional breeding to improve feed conversion efficiency, carcass composition and milk production. It may be argued that, as far as the conventional commercial breeds reared in the developed world are concerned, we are approaching the limit of what might be achieved by such techniques. Indeed, there is some evidence that we are already seeing negative impacts on reproduction and health of such animals and, perhaps, the quality of the meat produced. However, in terms of the developing world, many of the breeds traditionally farmed, due to their suitability to the climatic conditions, have not been subjected to such breeding programmes and it may be possible to achieve significant improvements in feed efficiency⁽¹⁸⁾.

Intensive rearing under restricted housing conditions has also been widely used to increase efficiency of meat production, particularly with regard to pigs and poultry. In more recent years, in industrialised countries, public perception of the impact such management systems on animal welfare has created a significant market meat derived from more conventionally-reared alternatives. By contrast, intensive farming has developed rapidly in emerging economies, particular in Asia, to meet the rapid increase in demand for meat⁽¹⁸⁾. It appears that for the present time, intensive farming of highly selected animals will remain a cornerstone of maximising the efficiency of meat production.

Current intensive farming practices, particularly of monogastric animals, are heavily reliant on the use of human-edible crops as feed. There is considerable interest in replacing such ingredients with less 'valuable' commodities such as fruit and vegetable waste⁽¹⁹⁾, by-products of the brewing or biofuels industries^(20,21) or locally grown forages and legumes⁽²²⁾. Potential problems with such novel feed sources relate to poor bio-availability of nutrients or presence of anti-nutritional factors. The addition of exogenous enzymes to animal feeds to aid digestion and absorption of nutrients may present a solution to such problems. As recently



reviewed, such enzymes are currently used to aid digestion of complex carbohydrates and break down phytate which is known to impede the absorption of phosphate and calcium⁽²³⁾. While such technology is now commonly used to aid in the digestion and absorption of high-quality human-edible feeds, there is considerable potential for their use in improving the nutritional value of lower-quality plant material. This may ultimately improve the nutritional value of agricultural and industrial waste and currently underutilised crops which have the potential to be grown under conditions unsuitable for traditional food/feed crops.

Considerable attention has recently been turned to the use of insects as feed for livestock. Insects represent a natural part of the diet of both aquatic and terrestrial wild animals from which domestic livestock have been derived. They are poikilothermic, have been suggested to have high feed conversion efficiency, have low greenhouse gas emissions and can be grown at high densities, thus reducing land use⁽²⁴⁾. As such their use as both a human food and an animal feed has generated considerable interest. Their use as animal feed relies on the development of production systems that utilise dietary substrates which cannot be directly fed to livestock (or indeed human subjects). To date, the use of insect larvae grown on animal excrement or household waste (including animal-derived material) has been demonstrated to be a potentially viable system in which to produce a high-protein quality feed that can be used in both aquaculture and monogastric farming^(25–27). However, within the Europe Union, where insects are regarded as ‘farmed animals’, the feeding of substrates such as manure, catering waste or former foodstuffs containing meat and fish is not allowed⁽²⁸⁾. As such, there is growing interest in the potential for using plant waste, or plant species not suitable for direct livestock production, as a substrate for insect production. The hope would be that the insects could be a vehicle for concentration of valuable nutrients and exclusion of anti-nutritional factors associated with such material. For example, recent studies compared the survival, development and composition of four different insect species fed diets formulated from different plant-based food by-products⁽²⁹⁾. The studies showed that in general Argentinian cockroaches and black soldier flies use feed more efficiently than yellow mealworms or house crickets. They also suggested that on suitable diets insects were more efficient at utilising protein than conventional livestock and that their composition could be altered through changes in their diet. While insects represent a promising option for producing high-quality animal feeds, particularly as an alternative to wild caught fish meal used in aquaculture, there are still a number of unanswered questions and safety concerns⁽²⁸⁾. In particular, their ability to transmit pathogenic organisms, accumulate toxic substances and the presence of anti-nutritional factors within insect-derived feed all require further investigation.

A more controversial way of improving production efficiency and sustainability of farm animal production is the use of growth promoters, metabolic modifiers and anabolic agents. Attitudes to such agents varies

considerably around the world⁽²³⁾. The European Union has banned their use while in other countries (including North America and Australia) their use is allowed but strictly regulated to minimise the likelihood of potential hazardous residues accumulating in the tissue of animals. Of more concern is the potentially unregulated use of such agents in other parts of the world which may well increase as the demand for improved efficiency increases. With the emergence of technology which facilitates the production of genetically manipulated farm animals, the production of transgenic animals (particularly pigs) with improved feed efficiency is also an active target for research⁽³⁰⁾.

Reducing meat consumption

While the strategies described earlier may help reduce the burden of meat production on global food security it remains uncertain whether production can meet the predicted demand for such products. As already described, meat (and dairy products) represents an important source of key nutrients and in those countries where malnutrition remains a significant problem there may be significant health benefits of increasing their consumption. However, there is little doubt that in more affluent countries excessive consumption of animal products is contributing to the burden of chronic disease. If nothing else, diets rich in dairy products and meat tend to be energy-dense and almost certainly add to the excessive consumption of energy and associated obesity. Beyond this, there is little evidence that excessive consumption of milk, poultry meat or fish have detrimental effects on health⁽⁴⁾. By contrast, excessive consumption of red, and particularly processed, meat has been associated with increased risk of both CVD⁽⁴⁾ and colorectal cancer^(4,31). While diets rich in such foods are often associated with other unhealthy lifestyle factors (including smoking, excessive alcohol consumption and physical inactivity), even when confounding effects of these have been excluded an independent effect of processed red meat consumption has been described⁽³²⁾. Thus, in addition to improving the sustainability of meat production, it would appear prudent to mitigate against the excessive consumption in many parts of the industrialised world. Such interventions may also help prevent intakes in countries within emerging countries increase to such inappropriate levels.

For most people in the Western world, complete elimination of red meat from the diet would not appear achievable. The consumption of such products is largely regarded as pleasurable and socially desirable⁽³³⁾. However, preliminary data from our group have demonstrated a significant proportion of UK meat eaters are actively trying to reduce red and processed meat intake⁽³⁴⁾. Of 1141 consumers surveyed over one-third indicated they are trying to reduce their meat intake. Most indicated that this was associated with a desire to lose weight, or other perceived health benefits, with far fewer indicating concerns about the impact of meat production on the environment. When questioned about strategies for

achieving reduction most favoured meat-free days (or meals), rather than alternatives such as meat replacers or potential future options such as cultured meat or insects. The potential for insects to replace meat in the diet may be more acceptable in countries where there is already a tradition for their consumption. However, it remains to be seen whether replacements of such dietary patterns with a more Westernised meat-rich diet will continue to be an aspiration of populations as wealth, and with it food availability, increases.

Conclusions

Meat and dairy products represent energy and nutrient-dense sources of nutrition which, when consumed together with a range of fruit and vegetables, can provide a diet which is conducive to life-long health. However, excessive consumption, particularly of processed red meat, is associated with susceptibility to a range of chronic diseases, in particular CVD and colorectal cancer. While milk and associated dairy products may contribute to excessive energy intake and hence obesity, they do not appear to have significant negative effects on health. Thus, while many parts of the world would benefit by increasing consumption of such animal products, a reduction in intake in the highest consumers in more affluent parts of the world would have significant benefits. There is increasing concern that increased demand for animal products, associated with population growth, increased lifespan and improving economic prosperity in the developing world, will put unsustainable demands on the environment which may be further impacted on by climate change. It therefore appears imperative that alternative husbandry techniques, including adoption of novel and more sustainable animal feeds should be combined with efforts to reduce meat consumption in more affluent parts of the world. By a combination of these interventions we may be able to maintain a sustainable level of meat and milk production.

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Conflicts of Interest

None.

Authorship

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