ROYAL AGRICULTURAL SOCIETY of ENGLAND

RSA

Milk in perspective

Milk is cheaper than water on the English High Street because generations of British farmers have embraced technology and constantly raised efficiency. They must continue with more of the same if world food demand is to be met.

1,000 litres of water *produces* **1 litre of milk**

to grow crops and water a cow

yet milk sells for less than a litre of bottled water.

The past 20 years have seen dairy efficiency increase in developed countries with milk yields increased by 25%. Today, a Holstein/Friesian in mid-lactation may produce 60L/day; compared to African pastoral production of just 2L/day. Initial intensification of agricultural systems in the Agricultural Revolution (1700–1860) inevitably led to disease emergence and spread. However, developments in vaccination, chemotherapy and hygiene allowed productivity gains to continue throughout the 20th Century. While refrigeration and containerisation opened up markets worldwide.

With human population forecast to rise from current (2008) numbers of around 6.6 billion to around 9.3 billion by 2050, food demand may almost double. Yet there are threats to productivity.

Growth in food demand could be offset by eating cereal and vegetables directly, or the world's 1.3 billion overweight people could eat less.

These outcomes are unlikely. Per capita consumption of meat and milk is forecast to increase substantially, particularly in developing countries, over the next 50 years.

Improved production efficiency will be the only viable option to meet demand and reduce environmental impact.

Improvements will embrace conventional breeding and genetic modification, precision irrigation and fertilisation, optimal nutrition and disease control. Efficiency must be enhanced worldwide and measures should support the comparative advantage of local climatic, soil and environmental conditions. Furthermore, prosperity and liberalised markets will be essential to ensure free trade securing food for all nations.

Milk is nutritious, tasty and cheap. Demand is increasing as global requirement for protein and energy grows. The current recession will pass and global prosperity will grow allowing more of us to enjoy the bounty provided by the humble dairy cow.

Key water statistics

1 calorie of food requires 1L water

1kg of meat requires 10,000L

74% of 'human use' worldwide is for agriculture

This summary is based on *'How can milk cost less than water?'*, the Royal Society of Arts President's Lecture 2009 by Professor Quintin McKellar, Royal Veterinary College; jointly sponsored by the RASE and RSA.

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Water is essential to life. Each person on the planet requires 3000 litres of water daily through direct consumption and, more significantly, indirectly for plant growth.

In temperate regions there is sufficient rainfall and enough water to produce food for the anticipated human population growth for the next 50 years. But over-exploitation poses significant threats. Some 900 million people worldwide live in river basins where demand exceeds capacity.

Despite readily available potable water, citizens in developed countries spend up to £1.16 per litre on bottled drinking water but only 67.4 pence per litre on milk (2009 prices) prompting the question: *"why does milk cost so little?"*.

Bottling water in developed countries is bizarre; it multiplies cost 10,000 times and absorbs energy in bottling and transportation which may equate to filling each bottle a quarter full with crude oil.

Whatever the reason for bottled water sales, it is extraordinary that a cow can be kept, fed, watered, housed and milked and that the product of her exquisite physiological machinery should cost less than water!

Milk has lost its attraction

The high energy content of natural milk – essential for new-born survival has lost its attraction in a world where globally more people are overweight (1.3 billion) than malnourished (0.9 billion) and where saturated fats are cast as major villains in coronary heart disease. Having bred and fed cows to produce milk with 4% fat we now extract fat to create skimmed products with less than 0.3%.

CULTIVATION, DOMESTICATION AND MECHANISATION

To understand why milk is so cheap it is necessary to consider the co-evolution of men and agriculture.

At the sunrise of agriculture, 10,000 years ago just ten million humans lived on earth as hunters-gatherers or nomads. Cultivation of grasses meant nutritional requirements of communities could be met from smaller land areas. Furthermore, calories could be stored as grain, levelling the effects of lean times. Production of grain also sustained domesticated animals. It is only relatively recently that fodder crops have been grown specifically for domestic animals.

Agricultural advancement

Agricultural enlightenment really got going from the start of the 18th Century when Jethro Tull invented the seed drill. Mechanisation over the past three centuries has improved production enormously. However nutrition and breeding have also had extraordinary impact on agricultural production.

Improved nutrition for plants and animals was enhanced by selective breeding based empirically on desired phenotypes (appearance).

Great leaps in agricultural production, over ten millennia, resulted in human population growth from 10 million to 6,000 million. Improved productivity meant plants, animals and man could live in ever decreasing space and greater intensity. So viruses, bacteria and parasites found their living conditions improved too.

Fighting disease

Having progressed mechanisation, nutrition and breeding such that they no longer limited production, man now looked to disease. It is inspiring to realise that in the UK, foot and mouth disease, rinderpest, bovine pleuropneumonia and sheep pox were all eradicated during the 19th Century without resort to vaccine or chemotherapy.

During the early 20th Century animal disease research institutes emerged that not only discovered important vaccines but also manufactured them before the pharmaceutical industry emerged. Some products, such as the clostridial vaccines produced by the Moredun Institute in Scotland, had extraordinary impact.

Agricultural progress has been spectacular but human reproduction has been equally impressive. Immediately post war, famine was a very present danger. However, crop and animal production rose to meet the challenge.

The power of genetics

Despite a period of apparent sufficiency, man's drive to improve agricultural efficiency remained relentless. The true power of genetics became apparent.

Progressive improvement in productivity, associated primarily with genetic selection, is apparent in the dairy cow. The milk yield of a Friesian/Holstein improved by 46% between 1957 and 2009. A combination of genetic selection and improved hygiene has led to average cell counts in the UK national herd dropping from 750,000 in 1968 to 180,000 in 1996. Genetic improvement has progressed from using selection indices for dairy sire evaluation pre-1980, to best linear unbiased prediction (BLUP). DNA techniques have developed which allow genes which produce specific traits in animals

to be identified. Markers are now available for milk production, udder health and feed efficiency.

The logical next step in genetic improvement was to manipulate the gene itself. The potential to produce more productive, disease or drought resistant, better keeping or better tasting food stuff, is legion. It was perhaps misguided that early commercial genetically modified (GM) crops were genetically resistant to the manufacturers' herbicides thus giving lie to the profit motive.

It is hypocritical to oppose genetic modification where genes are inserted or deleted in a controlled scientific and contained way, and yet accept massive progress made in plant genetics where mutants were created using x-rays, thermal neutrons and carcinogens. Genetic improvement has arguably made the greatest impact on agricultural production since the Second World War (disease control excepted) but husbandry and nutritional refinement have also contributed positively.

The use of antimicrobial agents as growth promoters has been discontinued in the EU because of the potential to select for antibiotic-resistant organisms. These organisms could transfer to man and could be directly pathogenic or transfer resistance genes.

Perhaps mechanistically less surprising, but no less controversial, steroids and growth hormones have also proved effective growth enhancers. Controversy exists in many countries over these products. While the fears are understandable, the risk in countries with well developed public health infrastructures is slight. Concern has been raised in the EU that increasing production from already highly productive cattle could contribute to mastitis and may have an adverse welfare impact on the animals. The World Trade Organisation has ruled that the EU cannot refuse meat or dairy products produced in the US on the basis of their use of hormone growth promoters or milk production enhancers since there is no scientific evidence that such use compromises safety.

BARRIERS TO PROGRESS

Having addressed nutrition, embraced genetics and utilised chemicals, developed scale, introduced mechanisation and affected markets, the efficiency of milk production might seem assured. But dark clouds gather on the horizon. As fast as drugs are produced, bugs adapt. The great genetic potential harnessed to squeeze production from our domestic animals is but nothing compared to the genetic potential of these microorganisms.

New technologies should have led to an ample pipeline of new drugs to replace those rendered redundant. This has not been realised as costs and risk of failure mean that only potential blockbuster products attract enthusiasm and investment. People seem happier to invest in improved libido and drugs to offset over-indulgence (anti-obesity) than anti-infectives. Furthermore the "low hanging fruit" has been harvested.

The environmental challenge

Environmental change, in particular global warming, will also impact dramatically on agriculture. Seventy percent of previously forested Amazonian land is now pasture. This impacts genetic diversity as grazing land replaces tropical forest diversity with an alien monoculture. Livestock impact the environment in other ways, it is estimated that about 73% of rangeland in dry areas has been overgrazed, eroded or compacted and thus degraded to some extent. Extensive areas of productive land have also been lost due to pollution, nutrient depletion, salinization and sea water intrusion.

Urbanisation has been a driver of agricultural productivity and a recipient of its bounty such that from 2007 more of humanity live in urban than rural environments. The huge consumption markets have been a magnet for livestock production which has migrated and intensified from rangeland to peri-urban factory. This has brought with it great concentration of potential effluent and pollutants contributing to negative environmental impact. It is likely that as the transportation costs of bulky fodder outweigh those of processed foods, intensive livestock production will migrate on a global scale towards the sources of animal feedstuff and in a sense back to its roots. At these locations (eg. Mato Grosso, Brazil; Corn Belt, USA) integrated food production chains will develop converting primary cereals into packaged (or chilled) meat product.

Livestock currently account for 18% of global greenhouse gas emissions (as CO_2 equivalent). The products of livestock production (methane and nitrous oxide) have highly detrimental global warming potential – respectively some 23 and 296 times that of CO_2. Livestock also produce 64% of all anthropogenic ammonia which contributes towards acid rain.

Without abatement, the livestock contribution to global warming will dramatically increase as growing wealth in developing countries accounts for greater animal protein and milk consumption.

The GHG contribution from livestock grazing rangeland at optimum stocking density or consuming crop by-products intended primarily for human consumption is probably trivial. Deforestation for cattle grazing and consuming fodder crops of human nutritive value has the greatest impact. In stark terms, it takes ten calories of cereal energy to produce each calorie

African pastoral production achieves just 2L/day

of animal energy. Fodder crops comprise approximately one third of all crop production (670 million tonnes of cereal). Furthermore irrigation – much used for fodder production – amounts to 277 million hectares representing 70% freshwater use and 93% water depletion.

In 2005 the US incentivised ethanol production. A significant and important by-product is dry distillers grains which can be fed to livestock. Distillers grains, fed carefully, provide an appropriate, essentially carbon neutral, source of nutrition.

Nitrogenous fertiliser plays a major role in crop productivity but has a major environmental impact. Production requires fossil fuel (natural gas) and generates some 41 million tonnes of CO_2 a year. Once applied, only about 50% of nitrogenous fertilisers are taken up by crops, the remainder leaches into the environment and may be a major pollutant. Livestock account for about 65% global N_2O emissions, a figure likely to increase as consumption of meat in developing countries grows. Dairy cows have high N and P requirement consuming up to 163.7kg and 22.6kg respectively each year, more than 70% of each is excreted. Food processing also has a major impact on pollution with slaughterhouses, tanneries and dairies making substantive negative contributions.

Livestock are treated with many drugs which are mostly metabolised in the animal or degrade rapidly in excreta. In developed countries environmental impact studies ensure products can be used without unacceptable impact. Indeed some products may have restrictions placed upon them in vulnerable ecologies.

ADDRESSING THE PROBLEMS

The challenge now is to feed a world population estimated to grow to about 9.3 billion by 2050 while reducing food production's impact on natural resources. It is likely to demand more intensive crop and livestock production. Efficiency will be key. Getting greater yields per litre of water or kg nitrogen will be essential. For livestock, diets optimised for nutrient intake to sustain good health and minimise GHG will be developed. Improvements in food conversion ratio by genetic improvement, following the poultry industry's example, will help reduce input and increase food production with reduced environmental impact. Globally, food security is critically dependent on liberal trade systems, adequate distribution and alleviation of poverty.

If harmonious equilibrium between global production and consumption can be achieved while addressing environmental concerns, then the contribution that a varied and "adequate" diet makes to human happiness should not be underestimated.

The environmental Kuznets curve suggests that as incomes increase, resource demand rises and impacts negatively on the environment. However, as incomes continue to rise society is willing to spend more to mitigate negative environmental impact. Continued prosperity is vital – particularly in developing countries.

So why does milk cost so little?

Milk is a commodity in which the UK has been self-sufficient for 50 years. It has suffered price distortions associated with subsidy and more recently intense competitive pressure that have depressed prices to such an extent that 23% of UK's dairy farmers went out of business (reduced farm numbers) between 2000 and 2005. Nevertheless, globally it is estimated that demand will increase from 580 million tonnes (1999) to 1043 million tonnes by 2050.

So how can milk cost less than water? Quite simply due to the continuing investment in, and appliance of, science and technology. Innovation has meant that not only has milk supply continued to keep pace with demand but the appliance of science on farms has enabled this feat to be performed with costs reducing in real terms. However, the challenge of population growth, urbanisation and improved global living standards means that we can only keep up that level of efficient performance if this and future generations continue to embrace science and technology. Given favourable public opinion, farmers can continue to reap the benefits of scientific progress, ensuring that milk will remain a nutritious and affordable food.