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REVIEW

Towards a sustainable dairy sector: Leadership in sustainable nutrition

GREGORY D MILLER and NANCY AUESTAD*

Dairy Research Institute, Rosemont, IL 60018, USA

As the global population continues to expand, access to sustainable diets that are nutritionally adequate and healthy, affordable, and respectful of biodiversity and ecosystems will be critical for the health of future generations. Nutrient-rich dairy products as part of a healthy diet play an important role in helping meet nutrient recommendations not easily met with other foods and can help lower risk of certain chronic diseases. The dairy industry worldwide is working across public and private sectors to continue to provide nutritious, affordable, culturally appealing dairy products while optimising natural resource use and reducing environmental impacts.

Keywords Dairy, Sustainability, Sustainable diet, Nutrition, Population growth, Nutrient rich.

*Author for correspondence. E-mail: nancy.auestad@rosedmi.com

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INTRODUCTION

Global population growth, projected to reach over 9 billion by 2050, will continue to drive demand for healthy, affordable food to sustain the health of future generations (Agricultural Development Economics Division of Economic and Social Development Department 2011). Advancements in agricultural and food systems in the face of limited natural resources, environmental and economic challenges and widely varying social systems globally are needed to meet future demands for food (Committee on Twenty-First Century Systems Agriculture and National Research Council 2010). Nutritionally adequate diets are essential for normal growth and development and for mitigating risk of both communicable and noncommunicable (chronic) diseases (US Department of Agriculture and US Department of Health and Human Services 2010). The prevailing obesity epidemic and issues of hunger and malnutrition across the globe make it critical that future agriculture and food systems not only deliver more food, but also more foods of sufficient nutritional quality to sustain a healthy population globally.

Over the past two decades, the concept of sustainable diets has evolved (Burlingame and Dernini 2012). While there is no universally accepted definition of a sustainable diet, the Food and Agriculture Organization (FAO) of the United Nations and Biodiversity International proposed a definition of sustainable diets as, '… those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe, and healthy; while optimizing natural and human resources' (Burlingame and Dernini 2012). This definition encompasses a multidimensional framework that recognises that human health and ecosystems are not independent of one another.

Across the dairy industry globally, dairy farmers, dairy processors, retailers and others are working together so they can continue to provide products that are nutritious, economically viable and produced responsibly (The Global Dairy Agenda for Action 2012). For the dairy industry, sustainability means providing consumers with the nutritious dairy products they want, in a way that is economically viable, environmentally sound and socially responsible – now and for future generations.

This article reviews the dairy industry's initiatives in the global challenges of population growth and climate change, the vital role of dairy foods as part of a healthy, sustainable diet and limitations of current research on environmental impacts of foods and diets in relation to developing dietary guidance for sustainable diets.

GLOBAL CHALLENGES

Global population growth and climate change will continue to be at the forefront of concerns about future human health and the sustainability of the planet. The global population is projected to increase from 7 billion today to more than 9 billion by 2050 with considerable growth in urban development expected (Agricultural Development Economics Division of Economic and Social Development Department 2011). The FAO estimates that to keep pace with projected population growth, a 70% increase in food production will be needed by 2050 (FAO 2009). Not only will more food be needed, but sufficient amounts of high quality, nutrient-rich foods will be essential for a healthy population.

Nutrition and health issues from hunger and malnutrition and the rising prevalence of chronic diseases across the globe are significant. Over the past several decades, the rise in the coexistence of hunger, malnutrition and chronic disease is especially concerning in light of expected population growth. The 2004 World Health Organization report, 'Global Strategy on Diet, Physical Activity and Health', stated that unhealthy diets and physical inactivity are among the leading causes of the major noncommunicable, chronic diseases, including cardiovascular disease, type 2 diabetes and certain types of cancer, contributing substantially to the global burden of disease, death and disability (World Health Organization 2004). Six of every ten deaths globally are due to noncommunicable diseases, three are due to communicable, reproductive and nutritional conditions largely in poorer populations and one to injuries (World Health Organization 2008). Leading causes of death by 2030 are projected to be heart disease, cerebrovascular disease (stroke), chronic obstructive pulmonary disease and lower respiratory infections, mainly pneumonia (World Health Organization 2008).

Social and economic development worldwide has led to an increased demand for energy (e.g. for housing, transportation, etc.), which has resulted in growing concerns about climate change, in particular greenhouse gas (GHG) emissions. The demand for energy through use of fossil fuels (coal, oil, gas) to power cars, factories and power plants and provide heat and electricity to homes and other places of business has increased substantially over the past 150 years (Intergovernmental Panel on Climate Change 2011). Greenhouse gas emissions also are formed in agricultural production and released from waste in landfills. Options for meeting future demand for global energy, while lowering GHG emissions from reliance on fossil fuels, include energy conservation measures, renewable energy and carbon capture and storage. Multinational programmes to reduce GHG emissions are in progress across all sectors, including the dairy value chain.

DAIRY INNOVATION

The dairy industry has had an impressive record of increasing productivity that has led to relatively affordable food for the population and increases in agricultural exports (Committee on Twenty-First Century Systems Agriculture and National Research Council 2010). Farmers worldwide face the challenge of producing more food for the expanding population while also addressing climate change, increasing production costs, limited natural resources and impacts on environmental and ecosystems. Future agricultural systems will evolve from an expanding knowledge base and the availability of affordable technologies to improve food production, enhance natural resource management and support the health of the population while minimising environmental impacts (US Department of Agriculture 2012).

Innovation to reduce the environmental impact of agricultural production while optimising use of natural resources will need to continue beyond the successes already achieved (FAO 2012). In the United States, for example, over the past 60 years, dairy farmers significantly enhanced agricultural productivity while concurrently reducing environmental impacts and reliance on natural resources. Milk yield per cow increased more than fourfold between 1944 and 2007, while using 90% less land, 65% less water, producing 75% less manure and leaving a 63% smaller carbon footprint per gallon of milk (Capper *et al.* 2009). In addition, over this period, milk production per cow increased 280 pounds per year, more than a tenfold greater rate of increase in productivity than the world's average per cow of 21 pounds per year (Figure 1).

Global Dairy Agenda for Action

Recognising the need for new technologies to produce more from fewer resources, the global dairy industry continues to

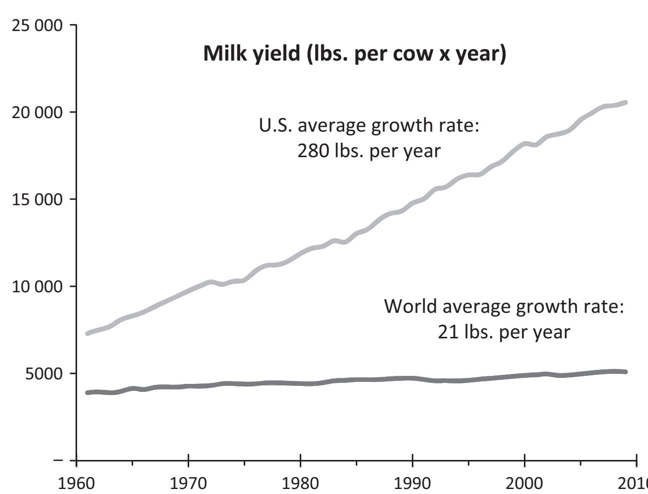

Figure 1 Changes in milk production from 1960 to 2010. Data are from FAO (2012).

evolve science and technology in ways to advance environmentally sustainable and socially responsible dairy production. The Global Dairy Agenda for Action, which was developed with input from across the global dairy supply chain and from a wide range of dairy producing countries, was signed in 2009 at the World Dairy Summit in Berlin (The Global Dairy Agenda for Action 2012). The participants recognised the need to raise awareness on the role of dairy production in climate change, as well as the contribution of dairy farming and dairy products to global nutritional, social and economic well-being. A wide range of dairy farming and industry organisations, national and regional dairy associations, and companies from throughout the dairy supply chain are actively working to improve the environmental performance of the dairy sector.

Progress continues as the dairy supply chain works with other stakeholders on key objectives. Initiatives to address climate change concerns have been launched around the world, and the Green Paper catalogues initiatives and progress through a multitude of case studies globally (The Global Dairy Agenda for Action 2012). The Green Paper has over 400 initiatives under six primary areas: emission reductions, energy efficiency, transport efficiency, reduction in loss of milk and milk products, resource efficiency and life cycle analysis and management. For example, the United Kingdom/Dairy Supply Chain Forum has developed a dairy road map and agricultural GHG action plan targeting a 20–30% voluntary reduction in GHG from dairy farms by 2030; other national and corporate GHG sustainability strategies include similar voluntary GHG reduction targets. Other examples include initiatives for soil management improvement in Australia, manure management in the United States and Great Britain, and energy efficiency both on-farm and in processing in Mexico, Japan and the United States.

Dairy sustainability measurement and reporting

In the United States, progress against a voluntary, industry-wide goal to reduce GHG emissions for fluid milk by 25 per cent by 2020 against a 2007/2008 baseline continues to be made. Life Cycle Assessment (LCA) methodology, the most recognised and widely used approach to analyse a product's environmental impacts through the entire life cycle of the product, was used to determine GHG emissions as well as other environmental impacts across the dairy value chain (Finkbeiner *et al.* 2006). Primary data were collected from 536 farms, 50 processing plants and 210 000 round trips transporting milk from farm to processor (Innovation Center for US Dairy 2011). Benchmarks of GHG emissions, water and other environmental impacts from the farm to the consumer are the baseline from which mitigation targets and measured improvements are made.

The US dairy industry accounts for approximately two per cent of GHG emissions in the United States, and 90% of the US dairy industry GHG footprint is explained by about 20 variables (Innovation Center for US Dairy 2011). On-farm management practices are more significant than factors such as farm size, region or type of business and opportunities for improvement exist across the entire dairy supply chain. Impacts from fuel and electricity, for example, span across all stages of the supply chain.

The Sustainability Measurement and Reporting Framework, developed by the Innovation Center for US Dairy, supports industry-wide initiatives to assess, measure, mitigate and communicate progress against commitments to reduce dairy's environmental impacts (Innovation Center for US Dairy 2011). Resources are being developed and becoming available to help farmers and businesses across the supply chain in the private sector to improve and communicate about the sustainability of dairy products (Innovation Center for US Dairy 2012). These resources also provide retailers, consumers, scientists and policymakers with consistent and credible information.

Roadmap to mitigate GHG emissions

From milk production on the farm through consumption by consumers, the dairy industry is working to both optimise the use of natural resources and reduce environmental impacts. Opportunities to reduce dairy's carbon footprint identified in the GHG Life Cycle Assessment for fluid milk in the United States include nutrient management practices, modifying feeding rations, manure management, energy efficiency, improved packaging formats, new processing technologies and fuel efficiency. Case studies and best practices can be found on USDairy.com/sustainability (Innovation Center for US Dairy) as well as the Green Paper at the Global Dairy Agenda for Action Website (The Global Dairy Agenda for Action 2012). Programmes already in place in the United States are exemplified.

Energy management best practices

The Farm Energy Efficiency™ programme promotes the adoption of existing best practices with a focus on reducing on-farm energy use and costs. Greenhouse gas emissions could be reduced by as much as 700 metric tons with the added benefit of energy cost savings to farms. Partnerships and multistakeholder collaborations foster a combination of energy education and outreach, on-farm energy audits and energy-efficient farm operations. The Dairy Plant Smart™ programme is designed to increase energy management at fluid milk processing plants and identify and adopt reduced-temperature cleaning technologies. A carbon calculator for milk processing plants is available at www.USDairy.com/PlantSmart. Users can benchmark their footprint against national averages, set goals and implement best practices.

Energy management next practices

The Next Generation Cleaning™ initiative is designed to identify and adopt reduced-temperature cleaning technologies.

In addition, many low-cost improvements can be made to existing equipment in processing plants and the fleets that transport milk. Energy management updates can improve system reliability, avoid maintenance and shutdown costs, increase productivity and add new revenue streams. In addition to energy efficiency, best practices to reduce GHG emissions include cogeneration and alternative energy sources, such as solar and wind.

Dairy distribution best practice

The Dairy Fleet Smart™ programme is designed to accelerate adoption of management practices that reduce fuel consumption, costs and GHG emissions in the transport and distribution of milk. A Dairy Fleet Smart tool to calculate a fleet's carbon footprint, set continuous improvement goals and realise transportation efficiencies is available at http://www.USDairy.com/Fleetsmart.

Enteric and manure management next practices

The Dairy Power™/Biogas Capture and Transport™ initiative fosters development of new business models to remove barriers for adoption of new practices. Dairy cows are one of the most dependable sources of renewable energy, and with anaerobic manure digester technology, farms can recover methane gas for use as renewable energy and transit fuel. The methane produced by cow manure is converted into biogas for use both on and off the farm. Manure digester systems can help reduce on-farm energy costs and can also provide communities with a renewable energy source, with opportunities for farmers to sell the energy for additional revenue. The Cow of the Future™ project is designed to identify ways to reduce enteric methane emissions from dairy cattle by improving breeding, nutrition and cow health. The project portfolio includes research for future innovations and improvements to produce even more milk with less impact on the environment.

MISPERCEPTIONS ABOUT EFFICIENCY OF THE DAIRY COW

Dairy cows are extremely efficient at converting human-inedible plant material into high-quality milk and are net contributors to the human food supply (Oltjen and Beckett 1996). However, misperceptions that dairy farming is an inefficient use of natural resources are pervasive. Dairy cows can digest cell-wall-rich plant material, including grass, straw and by-products. The nutrients in by-products that otherwise are a waste disposal problem are used to produce milk and milk products as part of the human food supply. In addition, land that is too poor or too erodible for crops can be productive with grazing ruminants.

Dairy cows eat mainly roughage (grass, hay, silage and by-products of the food and biofuel industries) and to varying extent concentrates, which help to maximise milk production. Concentrates are composed of varying amounts of both human-edible (e.g. corn grain, wheat, or barley) and inedible ingredients (e.g. almond hulls, citrus pulp, corn, gluten meal). Humans typically consume only the seed (e.g. corn kernel) where dairy cows can consume and extract nutrients from the entire plant (e.g. corn silage). Even with the many different types of dairy farming systems, by-products from human food production are fed to dairy cattle in all parts of the world regardless of farm size (Oltjen and Beckett 1996).

The efficiency of animal production in converting human-inedible plant material into human consumable energy and protein is informative for comparisons (Wilkinson 2011). When efficiencies of nutrient conversion (e.g. energy and protein) are calculated on a human-edible basis, dairy clearly adds to the total human food supply primarily as a result of the conversion of human-inedible inputs into human-edible milk (Wilkinson 2011; Gill *et al.* 2010; Council for Agricultural Science and Technology (CAST) 1999). Conservative estimates for the maximum return on the human-edible fraction in cow's feed, based on 1996 estimates in the United States, are 128% for energy and 276% for protein for human consumption. Other benefits of including livestock on farms include nutrient recycling through soil application of manure, improved living standards on family farms and employment opportunities in rural areas.

DAIRY, A VITAL PART OF A HEALTHY, AFFORDABLE, SUSTAINABLE DIET

The future health of the population worldwide will depend on nutritious, healthy, affordable diets that not only serve to achieve nutrient adequacy and are safe, but also are culturally and socially appealing across the many diverse populations worldwide. Population health is an important prerequisite for building and maintaining healthy, sustainable communities.

Dairy consumption falls short of recommendations in many countries

While current dairy consumption and dietary recommendations vary greatly across countries globally, many populations today fall short of recommended intakes. The 2009 European Health and Nutrition Report, which covers sixteen European Union countries over the years from 1993 to 2006, reported average dairy consumption at 266 g per day (European Nutrition and Health Report (2009)). Dairy intakes were highest in the Nordic countries of Denmark, Finland, Norway and Sweden and lowest in Austria. In Ireland, only 20% of adults consume the recommended 3 daily servings of milk, cheese and yogurt (Morgan *et al.* 2008). In Switzerland, only 10% of the population consumes the recommended 3 portions of milk and milk products (Eichholzer *et al.* 2010).

In Canada, about one-third of children 4–9 years old do not consume the recommended servings of dairy, and this gap increases as children reach adulthood (Statistics Canada 2006). For children 10–16 years old, 61% of boys and 83% of girls do not consume the recommended 3–4 daily servings, and for adults 31 years and older, 65–84% do not consume 3 daily servings of dairy foods. In the United States, only 4% of men and 12% of women consume the recommended 3 daily servings (Krebs-Smith *et al.* 2010). With the exception of 9 to 13 year-old girls, 90–95% of all females and 75–90% of adult men fall short of the recommended 3 daily servings of milk and milk products. In the United States, the average 1.7 dairy servings per day for everyone 2 years and older is only about half of the recommended 3 servings per day (Dairy Research Institute® 2009).

In China, milk consumption among children and adolescents has increased from about 3% in 1991 to 14% (Du *et al.* 2010). While average milk consumption has increased from 3.9 g per day in 1991 to 26 g per day in 2006, this is much lower than the Chinese dietary guidance of 300 g per day of dairy.

Diets fall short of nutrient recommendations

Similarly, many populations worldwide fall short of recommended nutrient intakes. Calcium, potassium, magnesium, vitamin D (where dairy products are fortified), vitamin B_{12}, iodine and protein are nutrients that are often under-consumed around the globe.

In the United States, for example, current intakes of calcium, vitamin D, potassium and fibre are low enough to be designated nutrients of public health concern, meaning current intakes are inadequate and linked to indicators of nutrient inadequacy or disease prevalence (Dietary Guidelines Advisory Committee 2010). Dietary intakes of calcium, vitamin D, potassium and fibre are at 75%, 28%, 56% and 40%, respectively, of recommended intakes (US Department of Agriculture and US Department of Health and Human Services 2010). The dairy group is an important food source of three of these nutrients – calcium, vitamin D and potassium-in the diet of Americans.

Dairy is a key source of nutrients and can fill nutrient gaps

Today, in the United States, more than half of the calcium and vitamin D that Americans get from all of the foods they eat is from consumption of dairy foods – even at current average intakes of 1.7 dairy servings for people 2 years and older. In fact, milk is the number one food source of calcium, vitamin D and potassium in the American diet. Additionally, about one-fourth of the vitamin A, vitamin B_{12}, phosphorus and riboflavin come from dairy (Figure 2).

Adding one more cup of milk or yogurt each day could not only help achieve the recommended 3 dairy servings per day, but can help close nutrient gaps, especially for the three nutrients of public health concern (Fulgoni *et al.* 2011). By adding a cup of milk or vitamin D fortified yogurt, calcium recommendations could be met and vitamin D and potassium intakes could be increased by at least 44 and 11 per cent, respectively.

Nutrient gaps can widen without dairy

Removing dairy foods from the diet will result in even further drops in the intake of essential nutrients, such as

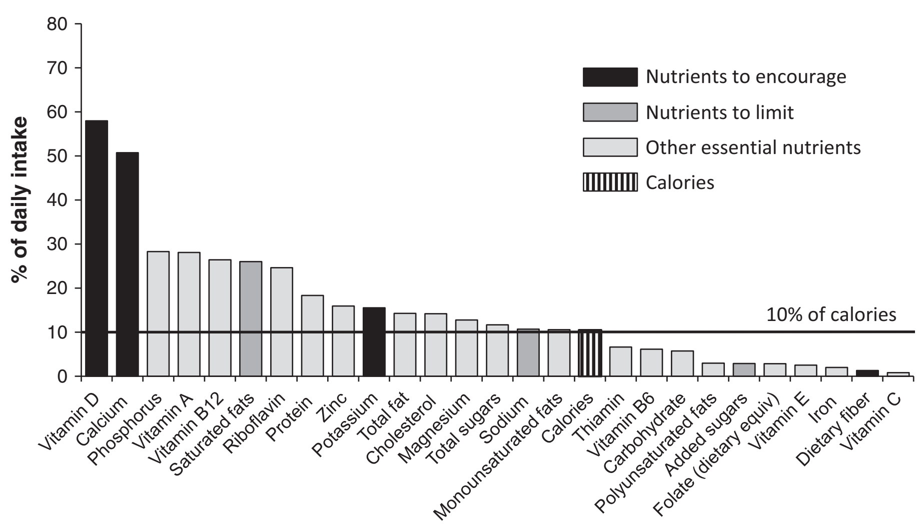

Figure 2 Contribution of current 1.7 servings of dairy products (milk, cheese and yogurt) to calorie and nutrient intakes in the United States. Nutrients to encourage and nutrients to limit are based on the 2010 Dietary Guidelines for Americans (US Department of Agriculture and US Department of Health and Human Services 2010). Nutrient and calorie intakes are from Dairy Research Institute® (2009).

calcium, vitamin D, potassium, vitamin A and choline (Fulgoni *et al.* 2011). It is not easy to replace dairy's nutrients with other foods.

Foods typically recommended as dairy substitutes, based on their calcium content, include fortified soy-based beverages, calcium-fortified juices, bony fish and dark leafy greens such as collard greens, kale, turnip greens and spinach (Dietary Guidelines Advisory Committee 2010). A diet modelling study based on national diet survey data in the United States showed that if dairy was replaced with a dairy composite of these milk alternatives, calcium intakes could be matched, but intakes of other essential nutrients in milk would be lower (Fulgoni *et al.* 2011). These dairy alternatives are not widely consumed, and significant dietary changes would be needed to meet nutrient recommendations without dairy. It is challenging for people, even those with nutritional knowledge, to develop eating plans that replace the nutrients from dairy foods when dairy foods are not consumed.

In addition, according to the U.S. 2010 Dietary Guidelines Advisory Committee, '… the amount of many potential alternatives to provide sufficient calcium would provide too many calories and/or be a large amount to consume daily. In addition, the question of bioavailability of the calcium in vegetable products has not been addressed and could pose a concern' (Dietary Guidelines Advisory Committee 2010). The cost of these substitute foods relative to dairy foods should also be considered.

The bioavailability of nutrients can be impacted by other components of foods that inhibit absorption, and the body's ability to absorb calcium is lower for some plant-based sources (Hunt 2003; Michaelsen *et al.* 2009). Phytates, which are compounds that are found in plant foods, can negatively impact the bioavailability of certain micronutrients including calcium. In populations with primarily plant-based diets, common in low-income countries, these compounds can have a negative impact on nutrient adequacy (Gibson *et al.* 2010). Animal foods, including dairy products, not only are excellent sources of many micronutrients but also contain few components that inhibit the bioavailability of the nutrients they provide.

Higher dairy intakes linked to lower risk of noncommunicable, chronic disease

A 2003 World Health Organization (WHO) report entitled, Diet, Nutrition and Prevention of Chronic Disease, stated, 'Nutrition is coming to the fore as a major modifiable determinant of chronic disease'(World Health Organization 2003). A subsequent 2004 WHO report further noted that unhealthy diets and physical inactivity are among the leading causes of the major chronic diseases and contribute substantially to the global burden of disease, death and disability (World Health Organization 2004). In the United States alone, if current trends are not reversed, the prevalence of total diabetes, including undiagnosed cases, could increase from the current 10% to between 20% and 33% of the population by 2050 (Boyle *et al.* 2010). A healthy dietary pattern based on nutrient-rich foods, including low-fat and fat-free dairy products, fruits, vegetables, whole grains and lean proteins consumed in recommended amounts is important for reducing the risk of chronic disease.

Evidence continues to mount that higher consumption of dairy products is associated with lower risk for developing chronic diseases including cardiovascular disease, type 2 diabetes and hypertension. The 2010 Dietary Guidelines for Americans recognises that dairy intake is linked to improved bone health, especially in children and adolescents and 'is associated with a reduced risk of cardiovascular disease and type 2 diabetes and with lower blood pressure in adults' (US Department of Agriculture and US Department of Health and Human Services 2010). After these guidelines were issued, more than seventeen observational studies and/or meta-analyses that further reinforce the role of dairy consumption on reducing risk for cardiovascular disease, elevated blood pressure, metabolic syndrome or type 2 diabetes have been published (Bonthuis *et al.* 2010; Warensjo *et al.* 2010; Fumeron *et al.* 2011; Malik *et al.* 2011; Margolis *et al.* 2011; Soedamah-Muthu *et al.* 2011, 2012; Sonestedt *et al.* 2011; Tong *et al.* 2011; Van Meijl and Mensink 2011; Dalmeijer *et al.* 2012; Grantham *et al.* 2012; Larsson *et al.* 2012; de Oliveira Otto *et al.* 2012; Ralston *et al.* 2012; Sluijs *et al.* 2012; Struijk *et al.* 2012).

Higher dairy intake linked to healthcare cost savings

Health benefits of higher dairy consumption translate into healthcare cost savings, which then can lead to a lower economic burden on healthcare systems. A review of nearly one hundred studies in 2004 concluded that increasing dairy consumption in the United States to 3 to 4 servings per day could lower risk of chronic diseases, including cardiovascular disease, type 2 diabetes and hypertension (McCarron and Heaney 2004). When translated to potential healthcare cost savings, this study found that 3 to 4 servings of dairy could result in savings of more than 200 billion dollars over a five-year time frame. The magnitude of potential healthcare cost savings today could be significantly greater when considering inflation over the past decade. A more recent study from Australia estimated direct healthcare expenditures and the burden of disease attributable to low consumption of dairy products and similarly concluded that increasing consumption of dairy foods to recommended amounts could lead to substantial improvements in health and lower costs for healthcare services (Doidge *et al.* 2012).

Dairy is affordable nutrition

Dairy products are an affordable way to help meet daily nutrient recommendations (Figure 3). In the United States, at about $0.26 per serving, milk and milk products cost less

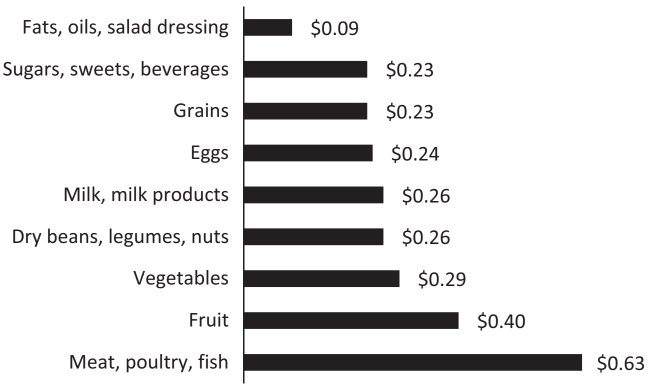

Figure 3 Average cost of food products by serving in the United States. Adapted from Drewnowski (2010). Costs shown are US dollars.

per serving than meat, poultry and fish, fruit, vegetables; similar to dry beans, legumes, nuts; and scarcely more than eggs, grains, and sugars, sweets, and other beverages (Drewnowski 2010). Cost analyses also have shown that milk and milk products are by far the lowest cost source of dietary calcium and among the lowest cost sources of riboflavin and vitamin B_{12} in the diet (Drewnowski 2010).

ENVIRONMENTAL IMPACTS OF FOODS AND DIET PATTERNS

Research on the environmental impact of foods and diets is beginning to emerge, but is still scant and inconclusive. The limited number of studies together with inconsistencies in the methodologies used to measure environmental impacts, the absence of a standardised environmental impact database for foods and differences in study designs, which limit comparisons across studies, are among the shortcomings of the existing research.

Five of the published studies examined the impact of individual food items on GHG emissions, including one study from Sweden that assessed an index of the nutrient richness of beverages to their climate (GHG emissions) impact (Weber and Matthews 2008; Carlsson-Kanyama and Gonzalez 2009; Smedman *et al.* 2010; González *et al.* 2011; Cederberg *et al.* 2012). Seven other studies examined the impact of various diet patterns on GHG emissions (Risku-Norja *et al.* 2009; Macdiarmid *et al.* 2011, 2012; Aston *et al.* 2012; Berners-Lee *et al.* 2012; Scarborough *et al.* 2012; Vieux *et al.* 2012) and four others on a broader range of environmental impacts that included food costs, nutrient intakes, fertiliser and pesticide use, production efficiencies, land requirements and scenarios on economics and dairy exports (Baroni *et al.* 2007; Marlow *et al.* 2009; Fazeni and Steinmüller 2011; Wolf *et al.* 2011). One study modelled the impact of fat and protein content in nutritionally complete diets on land carrying capacity for feeding a segment of the population (Peters *et al.* 2007).

Different approaches to assess the impact of dietary patterns have been taken. Some studies compared current diets with country-specific or global dietary recommendations (Peters *et al.* 2007; Risku-Norja *et al.* 2009; Fazeni and Steinmüller 2011; Macdiarmid *et al.* 2011, 2012; Wolf *et al.* 2011), others compared omnivorous with vegetarian and/or vegan diets (Baroni *et al.* 2007; Marlow *et al.* 2009; Berners-Lee *et al.* 2012), and a few employed models of diet scenarios that examined impacts of changes in the amounts of foods, food groups and/or calories within eating patterns (Aston *et al.* 2012; Scarborough *et al.* 2012; Vieux *et al.* 2012).

These studies form the start of an information base of research on the environmental, economic and social impacts of foods and dietary patterns. Methodological issues and other gaps will need to be addressed to build a solid information base. While most studies used the well-recognised LCA method to assess GHG emissions, some used an input–output method or a hybrid of the two methodologies. In addition, there was wide variability in boundaries for GHG emissions data – from assessment of GHG emissions primarily for agricultural commodities to using GHG emissions data only up to specific points in the life cycle (e.g. farm gate; distribution centres; retail). Some studies were interpreted as evidence for consumer education programmes or policy to encourage consumers to change their eating patterns, while others pointed out a clear need for more research. Several studies emphasised that assessing environmental impacts of foods or diets should not be restricted only to GHG emissions and that a pragmatic, realistic view that allows for differences in societal, cultural and religion and individual dietary preferences must be taken into account. A recent review examining challenges in defining a healthy diet with low environmental impact illustrates how food choices can impact health and GHG emissions, the most common assessment of environmental impacts in the published literature – and not always as may be expected (Macdiarmid 2013). The authors cautioned against making general assumptions and highlighted the comprehensive definition of sustainable diets put forth by the FAO noting the importance of considering nutritional implications, the whole diet rather than single foods, nutrition and environmental impacts of substitute foods, consumer acceptability and cost (Macdiarmid 2013). Currently, there are not enough high-quality studies with a broad enough scope (i.e. examining environment, economic and social factors together) available to determine dietary patterns that represent sustainable eating patterns.

CONCLUSION

It is critical for the health of future generations that the nutritional and health value of foods, including dairy products, be recognised when evaluating the sustainability of agricultural and food systems. The definition of sustainable diets put forth by the FAO of the United Nations and Biodiversity International is comprehensive with nutrition and health, biodiversity, economics and ecosystems as central components of sustainable development. Consistent and credible science that brings together agriculture, food systems, nutrition, public health, environment, economics, culture and trade is needed. The science currently available, however, is nascent and incomplete. Public health nutritionists and policymakers will need complete and solid evidence before dietary recommendations for sustainable diets can be developed.

Dairy foods are nutrient rich, affordable, accessible and consumed across the globe. Although dairy consumption falls short of recommendations in many countries, even at current intakes, dairy foods make substantial contributions to the intake of many essential nutrients. Higher dairy intakes are associated with lower risk of major chronic diseases and their associated healthcare costs.

The dairy industry worldwide is working together to provide nutritious, healthy products to support global population health in a way that optimises natural and human resources and reduces environmental impacts. Initiatives are underway globally through the Global Dairy Agenda for Action, and best practices from across the globe on the Green Paper Website demonstrate progress at all levels. For example, in Great Britain, procedures have been developed to improve manure management and reduce nutrient run-off; a thermal storage system that produces both energy and cost savings was adopted in Japan; and a Swedish dairy cut production waste in half by changing batch size and using fewer machines and lines. In the United States, measurement and reporting tools are becoming available to further enhance industry-wide efforts to reduce GHG emissions for fluid milk. The global dairy industry continues to lead the way to deliver nutritious dairy products that are responsibly produced, economically viable and environmentally sound.

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