Dairy and Meat: Implications for Human Health

Naomi K. Fukagawa, MD Ph.D.

USDA ARS Beltsville Human Nutrition Research Center, Beltsville, MD 20705

Introduction

The landscape for food production has changed dramatically over the last 70 years and continues to evolve as both populations and technology boom. Adaptation to the growing demands for the production of “healthy” food in a sustainable manner presents challenges beyond the pasture and the table. The implications for dietary guidance necessitates a better understanding of how production practices affect the nutrient quality of food and ultimately human health. The World Health Organization (WHO) presented its program for health for 2014-2019 that extended beyond just the prevention of disease. It focused on the changing world and the need to integrate solutions across disciplines to meet the needs of the rising population and changing demographics.

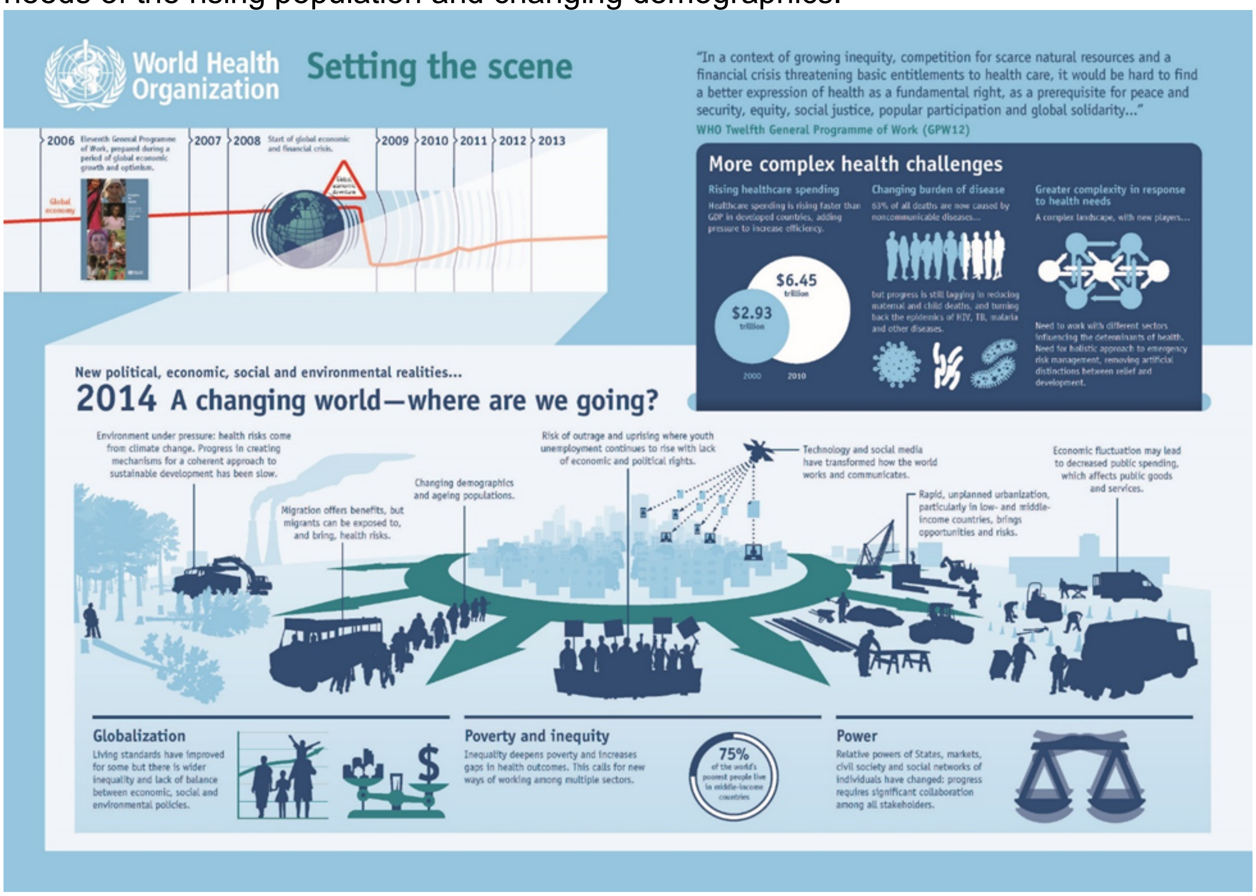

Figure 1. WHO 12th General Programme of Work 2014-2019 (Chapter 1)

Challenges Beyond Pasture and Table

The world population hit 7 billion in 2011 (United Nations 2017) and of those people, ~13% are hungry and ~32% of children in developing countries are malnourished (World Hunger Organization 2015). This plight starts during pregnancy in both the U.S. and the rest of the world. We know that, in general, food production is adequate but often not where food is needed most because of access, poverty, and social/political issues. Another challenge comes from the concern about the environmental impact of agricultural practices and climate change that affect soil quality, water availability, and choices that farmers must make. It is important to recognize that there is room for farms of all sizes, but how to maintain the workforce and public trust in where their food comes from remains unanswered.

Equally challenging is the uncertainty that people have about what constitutes a "healthy" plate. Scientists and nutritionists have recommended a shift to plant-based diets, but it is not clear whether this addresses the need to be culturally sensitive and whether this shift assures improved outcomes for people and the planet. Considerations for the beef and dairy industry include the ability to genetically select for specific traits in animals, how management of the herds influences the nutritional quality of the products and impact on the environment, and new products that meet evolving consumer choices/demands. From the human health perspective, beef and dairy provide a good source of protein, vitamins and minerals, bioactive compounds and potentially important oligosaccharides (complex sugars that link lactose with other monosaccharide building blocks such as glucose, galactose, fucose, sialic acid and N-acetylglucosamine). These sugar chains are reported to modulate immunity, act as prebiotics, and protect against some pathogens (Bode et al 2016).

Despite the many positive attributes related to beef and dairy foods and recent reports reevaluating relationships between fat and health outcomes (Pimpin et al 2016; Mozaffarian 2016), it will take time to change decades of dietary guidance that have recommended a reduction in intakes of saturated fats and red meat (e.g. Kritchevsky 1998; Dietary Guidelines 2015-2020). Monounsaturated fatty acids (MUFA) have long been reported to be associated with lower risk for coronary artery disease (Mensink et al 2003; Shingfield et al 2008). The beef and dairy industry have supported research on healthful aspects of meat and dairy and explored ways to alter nutrient content in their products. Relatively recently, Lehnert et al (2015) identified a genetic mutation that resulted in lower saturated fat and higher content of monounsaturated fatty acids (MUFA) in milk produced by the mother and her offspring. This demonstrates the feasibility of selecting for specific heritable traits that lead to production of milk with a preferred fatty acid profile. Figure 2b shows the mother and Figure 2c shows the lower saturated fat (blue) and higher MUFA (red) in milk from the daughters carrying the mutation.

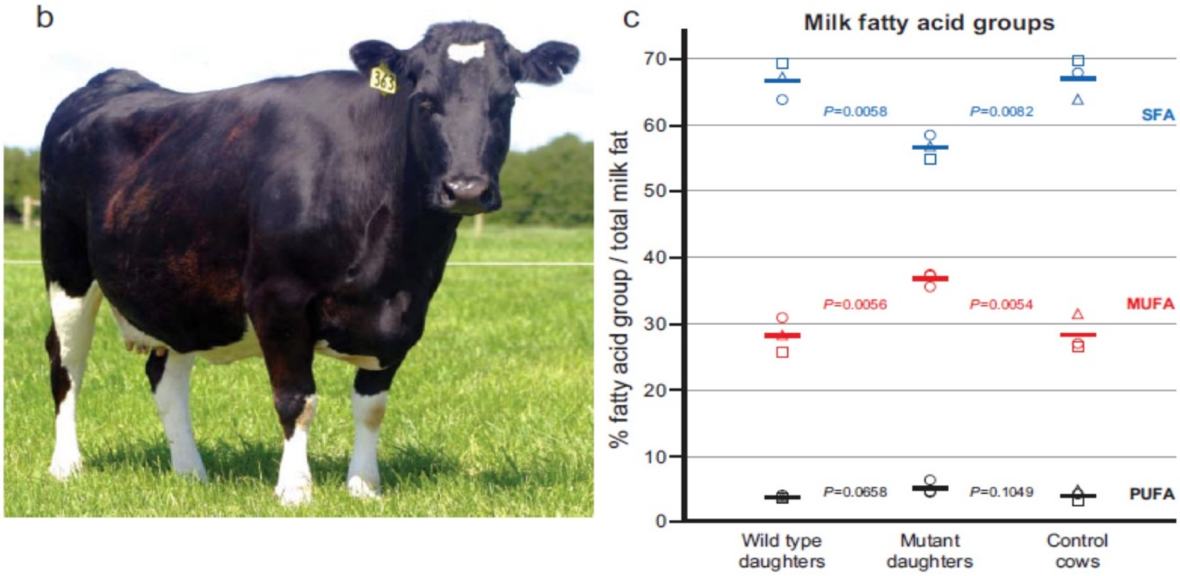

Figure 2. b. Cow with heritable mutation responsible for low milk fat content. c. Segregation of milk fatty acid composition in the F1 generation.
Milk contents of saturated (SFA, blue), monounsaturated (MUFA, red), and polyunsaturated fatty acids (PUFA, black) for three individual mutant and wild-type daughters of cow 363, and for three unrelated, breed-matched control cows in the same herd, are indicated by open symbols. Means are indicated by bold horizontal bars, and P values (two-tailed Student's t-test) for fatty acid groups differences are stated between genotype groups. Differences between wild-type daughters and control cows were not significant (PSFA50.96, PMUFA50.96, PPUFA50.93).

Another potential way to influence the nutrient profiles of milk is through the diet. Rumen microbiota are active in lipid metabolism, and it is known that the composition of the diet and type of lipid supplements interact to affect fatty acid profiles in milk fat (Shingfield et al 2008). Bioactive fatty acids in dairy products include alpha-linolenic acid (ALA), conjugated linoleic acid (CLA) and vaccenic acid (VA); all reported to have beneficial health effects such as reducing inflammation and lowering risk for type 2 diabetes mellitus and cardiovascular diseases (Bainbridge et al, 2016; Shingfield et al, 2008)). Forage species in pastures and degree of maturity have been shown to alter the fatty acid composition of grazing animals (Shingfield et al, 2008; Daley et al, 2010). Bainbridge et al (2016) recently reported that the content of bioactive fatty acids in milk is influenced by the breed of the cow, time of lactation, as well as the diet provided during lactation, supporting the contention that the number of bioactive compounds in in milk can be modulated through breeding and specific feeding regimens. Branched-chain fatty acids (BCFA) are another class of bioactive fatty acids in milk reported to exert anti-tumor effects, reduce the incidence of necrotizing enterocolitis in infants and improve pancreatic beta-cell function (Bainbridge et al 2016). Total BCFA concentrations in human milk at 4 weeks postpartum have also been recently examined and shown to differ between mothers from different parts of the world and influenced by diet (Dingess et al, 2017). In other work, branched short-chain fatty acids (e.g. isobutyric and isovaleric acids) generated by fermentation of branched chain amino acids from undigested protein reaching the colon were found to modulate glucose and lipid metabolism in fat cells (Heimann et al 2016). The interactions between food and the microbiota of the rumen as well as the gut need to be better understood but will likely serve as novel ways to influence the nutritional value of dairy products.

Other components in milk that may contribute to beneficial health effects include complex sugars known as oligosaccharides. A range of health benefits are attributed to human milk oligosaccharides (HMO) but research has been limited because of difficulty in its isolation or synthesis. Nevertheless, work continues on the use of nonhuman oligosaccharides and efforts are focusing on ways to use bovine milk oligosaccharides as precursors for synthesis of HMO's (Bode et al, 2016).

Red meat remains an important source of essential amino acids (building blocks of protein), and important vitamins (A, B_6, B_{12}, D and E) and minerals (iron, zinc and selenium). Although concerns have been raised about saturated fat in red meat, finishing diets can alter the lipid profile in a way to improve upon the final nutrient profile as reviewed by Daley et al in 2010. In addition, Bainbridge et al (2016) suggested that the content of BCFA could be modulated by both breed and diet. Clearly, more research through partnerships between academia, producers, consumers, and government is needed.

References

Bainbridge ML, Cersosimo LM, Wright ADG, Kraft J. Content and composition of branched-chain fatty acids in bovine milk are affected by lactation stage and breed of dairy cow. PLoS One. 2016. 11(3): e0150386. doi:10.1371/journal. pone.0150386

Bode L, Contractor N, Barile D, Pohl N, Prudden AR, Boons GJ, Jin YS, and Jennewein S. Overcoming the limited availability of human milk oligosaccharides: challenges and opportunities for research and application. Nutr Rev. 2016. 74(10):635.

Daley CA, Abbott A, Doyle PS, Nader GA and Larson S. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr J. 2010; 9:10.

Dingess KA, Valentine CJ, Ollberding NJ, Davidson BS, Woo JG, Summer S, Peng YM, Guerrero ML, Ruiz-Palacios GM, Ran-Ressler RR, McMahon RJ, Brenna JT, Morrow AL. Branched-chain fatty acid composition of human milk and the impact of maternal diet: the Global Exploration of Human Milk (GEHM) Study. Am J Clin Nutr. 2017 Jan;105(1):177-184. doi: 10.3945/ajcn.116.132464. Epub 2016 Nov 30.

Heimann E, Nyman M, Pålbrink AK, Lindkvist-Petersson K, Degerman E. Branched short-chain fatty acids modulate glucose and lipid metabolism in primary adipocytes. Adipocyte. 2016 Oct 28;5(4):359-368. eCollection 2016 Oct-Dec.

Kritchevsky D. History of recommendations to the public about dietary fat. J Nutrition. 1998. 128 (2): 449S.

Mensink RP, Zock PL, Kester AD, Katan MB. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials. Am J Clin Nutr. 2003 May;77(5):1146-55.

Mozaffarian D. Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity: A Comprehensive Review. Circulation. 2016 Jan 12;133(2):187-225. doi: 10.1161/CIRCULATIONAHA.115.018585.

Pimpin L, Wu JH, Haskelberg H, Del Gobbo L, Mozaffarian D. Is Butter Back? A Systematic Review and Meta-Analysis of Butter Consumption and Risk of Cardiovascular Disease, Diabetes, and Total Mortality. PLoS One. 2016 Jun 29;11(6): e0158118. doi: 10.1371/journal.pone.0158118. eCollection 2016. Review.

Shingfield KJ, Chilliard Y, Toivonen V, Kairenius P, Givens DI. *Trans* fatty acids and bioactive lipids in ruminant milk. In Bioactive components of milk, Advances in experimental medicine and biology (ed. Z Bösze), 2008. 606:3-65. Springer, New York, U.S.

U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans 2015-2020, 8th Edition. https://health.gov/dietaryguidelines/2015/guidelines/

United Nations, Department of Economic and Social Affairs, Population Division. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. Working Paper No. ESA/P/WP/248.

World Health Organization. The 12th General Programme of Work - Not merely the absence of disease. GPW/2014-2019. Chapter 1. Setting the Scene. 2014. http://apps.who.int/iris/bitstream/10665/112792/1/GPW_2014-2019_eng.pdf?ua=1

World Hunger Organization. http://www.worldhunger.org/2015-world-hunger-and-poverty-facts-and-statistics/