Impact of consumption of animal products on cardiovascular disease, diabetes, and cancer in developed countries

A. M. Salter

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

Implications

- Meat and milk represent an energy-dense, protein-rich food source that also contributes significantly to the required intake of a range of micronutrients. With increasing economic prosperity, populations tend to increase their consumption of such animal products. However, in the longer established "developed" countries, there has been a significant shift from red meat and full-fat milk toward poultry and fat-reduced dairy products.

- While premature death from cardiovascular disease has decreased dramatically in many developed countries, the prevalence of the disease remains high. High intake of saturated fatty acids contributes to the development of cardiovascular disease by increasing plasma cholesterol. However, recent evidence suggests that replacing saturated fatty acids with unsaturated fatty acids is more beneficial than replacing them with carbohydrates. While very high intakes of meat, particularly processed meat, may be associated with increased risk of cardiovascular disease, at more modest intakes where it is consumed as a part of a varied diet containing appropriate sources of unsaturated fatty acids, there is little evidence of any deleterious effect.

- Eating energy-dense diets, combined with the sedentary lifestyle adopted by many individuals in developed countries, has resulted in incidences of obesity of almost epidemic proportions. In time, a significant number of obese individuals become insulin resistant and develop metabolic syndrome, a cluster of risk factors that predispose the individual to both cardiovascular disease and type 2 diabetes.

- Even at relatively high intakes, there is little evidence that milk has any significant adverse effects on health and may be protective against cardiovascular disease, metabolic syndrome, and colorectal cancer. While other dairy products certainly contribute to consumption of saturated fatty acids, evidence for negative, or positive, effects on health is limited.

Key words: cancer, cardiovascular disease, dairy, diabetes, health, meat

Introduction

While debate continues over the relative consumption of animal and plant material by our early ancestors, in the modern human diet, meat and dairy produce can provide an energy-dense source of nutrition throughout the human lifespan. In US children aged between 12 and 24 months, it has been estimated that milk and cheese provide 28, 44, and 36% of total energy, protein, and vitamin A intake, respectively (Fox et al., 2006). Data for older children (4 to 10 years) in the UK indicate that meat and milk products provide 31 and 22%, respectively, of total protein intake (Bates et al., 2010). In UK adults, meat provides approximately 40% of the average daily protein intakes, though it should be noted that intakes are well above the Reference Nutrient Intakes at all ages (Bates et al., 2010). In addition, red meat makes a significant contribution to intakes of thiamin, niacin, vitamin B_{12}, iron, zinc, potassium, and phosphorus (Wyness et al., 2011). While deficiency of many of these nutrients is rare in developed countries, concerns have been expressed about vitamin B_{12} and zinc intakes in some non-meat eaters (Key et al., 2006). Red meat also makes a significant contribution to the intake of long-chain n-3 fatty acids, which may be particularly important when there is a low intake of oily fish. Milk and dairy products make a further major contribution to adult protein intakes and provide significant proportions of our requirements for calcium, phosphorus, iodine, vitamin A, and riboflavin (Kliem and Givens, 2011). It is against this nutritional context that we must consider any potential negative effects of animal products on non-communicable diseases (**NCD**).

Trends in Non-Communicable Disease and Animal Product Consumption

Non-communicable diseases, particularly cardiovascular disease (**CVD**) and type 2 diabetes, have traditionally been considered diseases of the developed world, associated with affluence, over-consumption of energy-dense foods, and lack of physical activity. With an increase in economic prosperity, many populations appear to increase their consumption of animal products, and it is inviting to associate increased susceptibility to NCD with increased intake of such foods. However, it is important to recognize that such diseases occur throughout the global population (WHO, 2011). In fact, the data presented in Table 1, comparing premature death from NCD in a range of countries, indicate that, on an age-standardized basis, death from CVD and diabetes is greatest in those countries

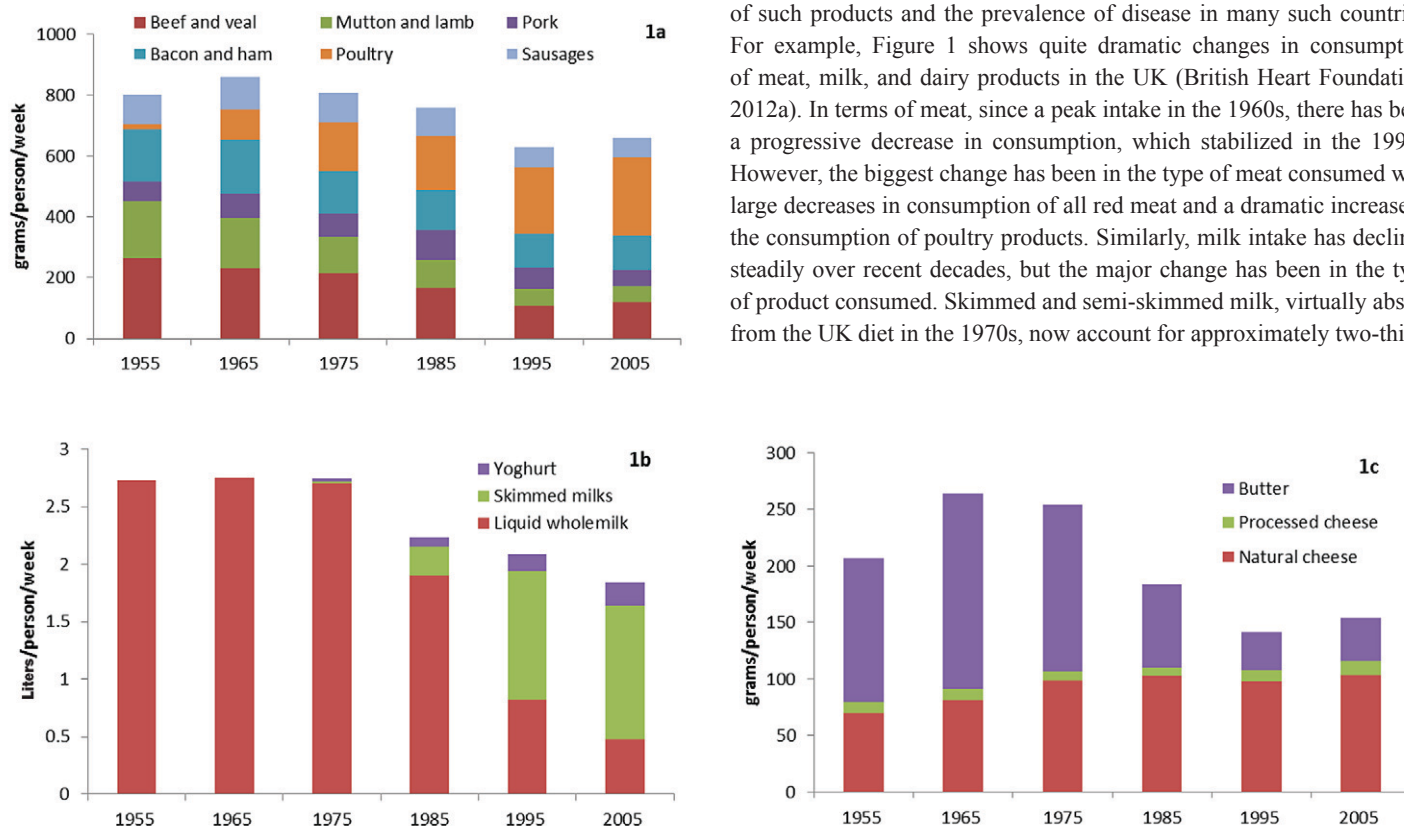**Table 1. Death from non-communicable diseases (NCD) and animal product consumption in selected countries.**

Country	Population (1000s)	Sex	Life expectancy (yr)[2]	Total deaths from NCD (1000s)[3]	% under age of 70 yr[3]	Age standardized deaths per 100,000 of population[3]			Livestock product consumption (kcal/person/day)[4]
						Total NCD	Cancer	CVD+ diabetes	
Brazil	189,300	Male	70.0	474	52	614	136	304	603.2
		Female	76.9	420	42	428	95	275	
China	1,318,000	Male	72.2	4,323	44	665	182	312	610.0
		Female	75.8	3,675	32	495	105	260	
India	1,132,000	Male	63.1	2,967	62	781	79	386	125.3
		Female	66.1	2,274	55	571	72	283	
Kenya	36,900	Male	57.6	57	59	780	119	401	216.6
		Female	62.1	47	52	575	113	326	
UK	61,000	Male	78..0	244	29	441	155	166	850.5
		Female	82.2	274	18	309	115	102	
US	302,200	Male	76.0	1,055	37	458	141	190	900.0
		Female	80.9	1,150	24	325	103	122	

[1]2007 data (Population Reference Bureau, 2007), [2]2009 data (WHO, 2012), [3]2008 data (WHO, 2011), [4]2005 data (FAO , 2009).

where consumption of animal products is lowest (India and Kenya) compared with those with a high intake (UK and US). Comparing mortality data between countries should be undertaken with caution as mortality, as opposed to prev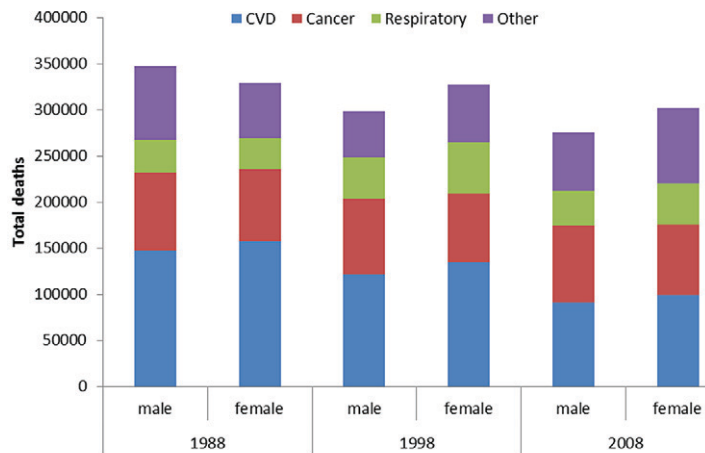alence of the disease, may be severely influenced by differences in health care availability. However, the data do clearly illustrate that such NCD are multi-factorial, and at worst, consumption of animal products is only one of a range of factors that influence the impact of such diseases on morbidity and mortality.

Any consideration of the impact of animal products on health in developed countries needs also to take account of changes in both consumption of such products and the prevalence of disease in many such countries. For example, Figure 1 shows quite dramatic changes in consumption of meat, milk, and dairy products in the UK (British Heart Foundation, 2012a). In terms of meat, since a peak intake in the 1960s, there has been a progressive decrease in consumption, which stabilized in the 1990s. However, the biggest change has been in the type of meat consumed with large decreases in consumption of all red meat and a dramatic increase in the consumption of poultry products. Similarly, milk intake has declined steadily over recent decades, but the major change has been in the type of product consumed. Skimmed and semi-skimmed milk, virtually absent from the UK diet in the 1970s, now account for approximately two-thirds

Figure 1. Trends in consumption of a) meat, b) milk, and c) dairy products in Great Britain. Redrawn from data presented by the British Heart Foundation (2012a).

Figure 2. Trends in causes of mortality from non-communicable diseases, in men and women, in the United Kingdom. Redrawn from data presented by the British Heart Foundation (2012b). CVD = cardiovascular disease.

Figure 3. Trends in cardiovascular disease in men and women in Great Britain: a) Age standardized mortality in men and women under the age of 75 years and b) prevalence of cardiovascular disease by sex. Redrawn from data presented by the British Heart Foundation (2012b).

of consumption. While cheese consumption has remained relatively constant, butter has largely been replaced by low-fat plant-derived spreads.

As already suggested, relying on mortality data to describe trends in NCD can be somewhat misleading. Figure 2 compares trends in total deaths, and their causes, in men and women over the last three decades (British Heart Foundation, 2012b). In general, the total number of deaths has steadily decreased, an effect that is more significant in men than women. In terms of cause of death, while the total number from CVD has dropped progressively, at each time point, more women have died from CVD than men. By contrast, deaths from cancer have been similar between the two sexes and are similar in each of the decades shown. If premature CVD mortality (below the age of 75 years) is shown on an age-standardized basis, then the decline has been much more dramatic and the well-recognized lower incidence in women is clearly evident (Figure 3a). However, Figure 3b shows data for prevalence of CVD, over the same time period, and shows a very different picture. Between 1988 and 2006, there was a steady increase in prevalence in both sexes. Thus, improvements in treatment and reductions in risk factors, particularly smoking (Unal et al., 2004), appear to have reduced premature mortality (below the age 75 years) from CVD and probably delayed the onset of the disease. However, in our aging population, the overall burden of CVD on morbidity has steadily increased.

Animal Products and Cardiovascular Disease

The link between intake of animal products and risk of developing CVD has largely been attributed to the relatively large contribution such foods make to our intake of saturated fatty acids (**SFA**). Figure 4 shows that meat, meat products, milk, and dairy products contribute approximately half of the intake of SFA in the UK.

While it is generally accepted that the quantity and composition of dietary fat can affect plasma lipoprotein cholesterol concentrations (Mensink et al., 2003), the impact of dietary fat on actual CVD morbidity and mortality has continued to be a topic of debate. The link between diet and development of disease can be explored in a number of ways. The most persuasive evidence arises from randomized control trials, where a dietary
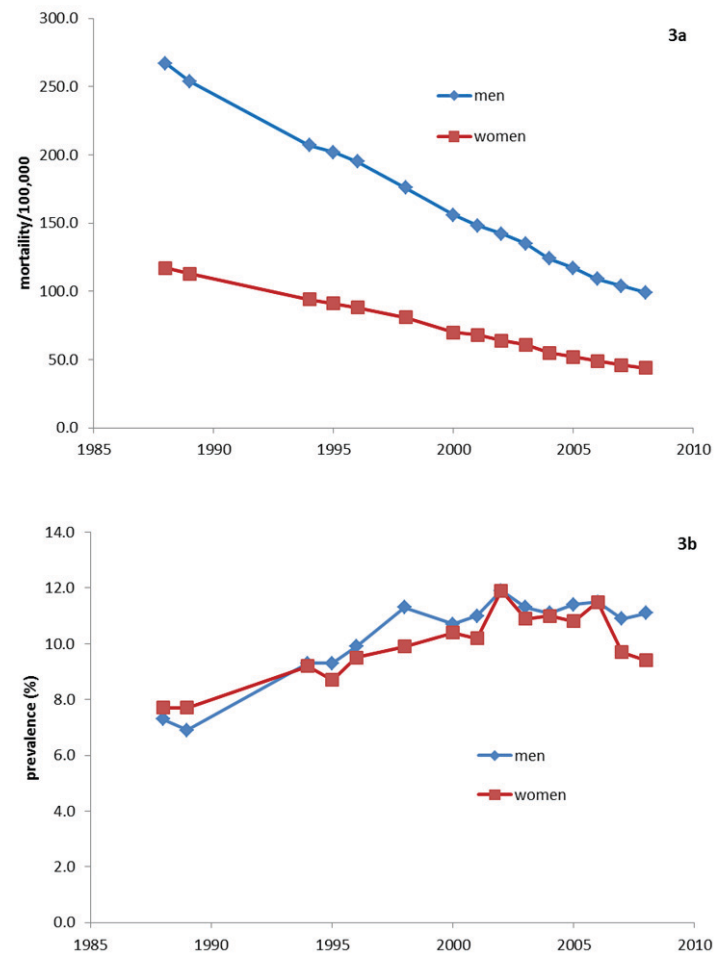
constituent is either added or removed and the impact on future disease incidence is monitored. In general, such studies are difficult to perform on free-living populations and are prohibitively expensive, due to the length of follow-up required to record sufficient disease incidence. Much of our understanding of the link between diet and NCD is therefore reliant on prospective cohort data, where the habitual diet of a group of individuals is determined and the subsequent incidence of disease monitored. Pooling data from such studies in a systematic review, ideally including a statistical "meta-analysis" often provides the most definitive evidence available.

A number of such systematic reviews have recently revisited this question and were described in detail (Salter, 2011). Table 2 summarizes the results of some of the more recent analyses of the impact of SFA. Overall, the results suggest that simply replacing SFA with carbohydrate is of limited benefit. However, substitution of SFA with unsaturated fatty acids has repeatedly been shown to reduce CVD morbidity and mortality. For example, a review by Hooper et al. (2011), which included 65,508 participants from 48 randomly controlled trials concluded that long-term (greater than two years) reduction of SFA intake was associated with a significantly (14%) reduced cardiovascular risk when it was substituted with unsaturated fatty acids rather than replaced with carbohydrates. Sim-

Table 2. Selected recent meta-analyses of the impact of saturated fatty acids on cardiovascular risk.

Study	Major conclusions
Jakobsen et al. (2009)	Based on 11 cohort studies: replacement of saturated fatty acids (SFA) with polyunsaturated fatty acids (PUFA) rather than monoun-saturated fatty acids (MUFA) or carbohydrate prevents CHD over a wide range of intakes.
Skeaff and Miller (2009)	Based on 26 cohort studies: CHD mortality not associated with total fat, SFA, MUFA. Data on total PUFA intake inconsistent with a significant increase in CHD death in those consuming the highest intake but paradoxically a significant reduction in CHD events associated with a 5% increase in PUFA intake. Based on 9 randomized control trials: while CHD mortality was not associated with total fat intake, PUFA/SFA ratio, CHD events were significantly reduced by a high ratio.
Siri-Tarino et al. (2010)	Based on 21 cohort studies: no significant evidence for concluding that dietary SFA is associated with risk of CHD, stroke, or total CVD.
Mozaffarian, Micha, and Wallace (2010)	Based on 8 randomized control trials: replacing SFA with PUFA reduces CHD events.
Hooper et al. (2011)	Based on 48 randomized control trials: replacing SFA with unsaturated fat reduces incidence of cardiovascular events. Analysis could not find any clear differential between replacing with PUFA or MUFA. Effects were only evident in trials with a duration of greater than 2 years and only in men. Replacing SFA with carbohydrate was not clearly protective.

ilar analyses appear to confirm the deleterious effect of trans fatty acids (**TFA**) on CVD risk (Salter, 2011). As many countries develop policies to reduce TFA derived from hydrogenated vegetable fats from our diets, animal products (specifically those derived from ruminant animals) have become a significant source of residual intakes. The potential impact of "ruminal" TFA is discussed below.

As already indicated, animal products make a significant contribution to total SFA intake in developed countries. Figure 5 indicates the amount of different classes of fatty acid associated with the major meats consumed. These data illustrate that red meats (beef, lamb, and pork) contain significantly more total fat than chicken and that the latter contains a significantly lower proportion of SFA. It should also be noted that the fatty acid composition of poultry and pork are significantly influenced by the diet of the animals. As monogastrics, much of the dietary fatty acids are absorbed from the intestine intact and may accumulate in both adipose tissue and muscle. In ruminants, the situation is considerably different. Ruminal biohydrogenation and the major contribution of de novo lipogenesis to fat stores mean that, even though the diets of these animals are relatively rich in unsaturated fatty acids, muscle and fat tissue tend to be relatively rich in SFA.

So, does the relatively high SFA content of red meat mean that consumption is inevitably associated with increased risk of developing CVD? This question was addressed in a recent systematic review by Micha et al. (2010). They undertook a meta-analysis of four studies including a total of 56, 311 participants and reporting 769 coronary heart disease (**CHD**) events and found no association between the consumption of red meat and CHD risk. By contrast, the same review considered data pooled from five studies (614,062 participants and 21,562 events) looking at the impact of processed meat (generally defined as that preserved by any method other than freezing) and suggested a 42% increase in risk associated with each 50-g daily serving. However, analysis of data from the Nurse's Health Study in the US suggested that, at least in females, total meat, total red meat, and red meat excluding processed meat were all associated with increased risk of CHD (Bernstein et al., 2010). These data were recently combined with that of the Health Professionals Study, which followed a large cohort of US
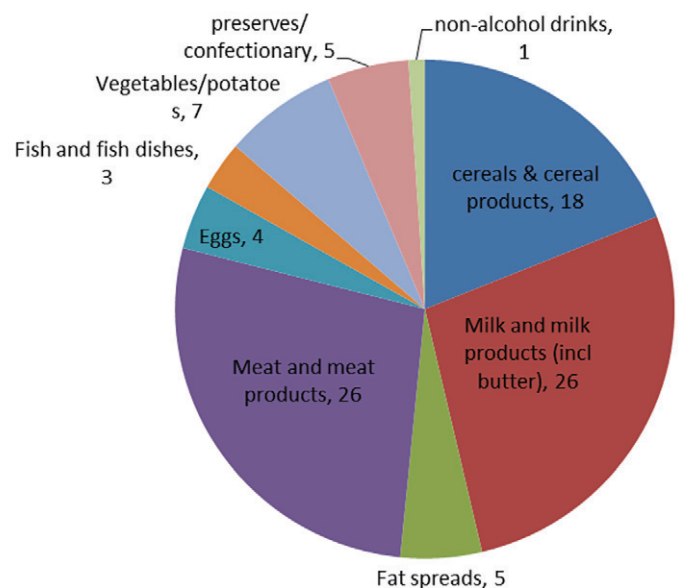
Figure 4 (*above*). Contribution of different food groups to saturated fatty acid intake in the United Kingdom in 2008–2009. Redrawn from National Diet and Nutrition Survey data presented by the Food Standards Agency (2010).
Figure 5 (*below*). Fatty acid composition of select meats. Redrawn from data presented by Wyness et al. (2011).
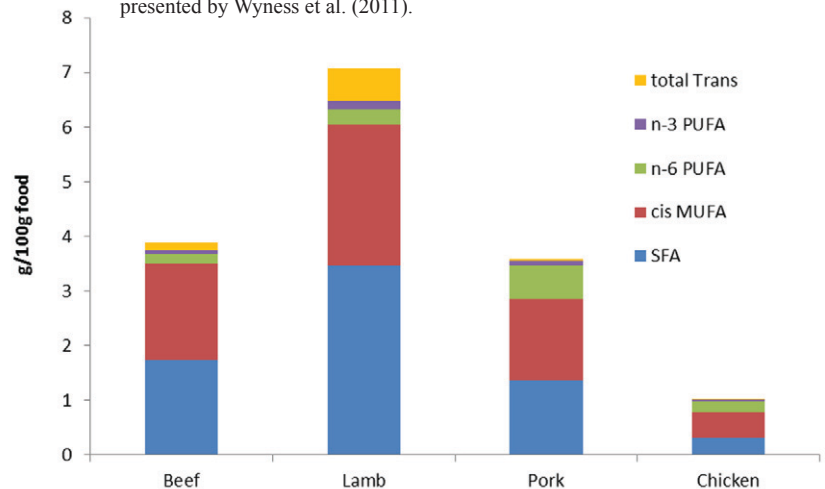
males, and while the association between processed meat and CVD was stronger, fresh red meat consumption was also positively associated with increased risk (Pan et al., 2012). This study highlighted the large differences in meat consumption that exist within the US, ranging from a mean of 0.22 servings per day (of total red meat) in the lowest quintile of intake in the Health Professionals Study to 3.10 servings per day in the highest quintile of the Nurse's Health Study. It also highlighted that high meat intake is frequently associated with an increase in other potential risk factors including total energy intake, increased body mass index (**BMI**), reduced physical activity, and increased likelihood of smoking. However, even after correcting for these potential confounders, the authors demonstrate a residual risk associated with intake of both fresh and processed red meat. This study also addressed the question as to whether it is the SFA content of red meat that is associated with the increased risk of CVD. While this appeared to make a significant contribution, even after correcting for SFA, a residual risk was still apparent. The authors suggest that this may be associated with greater heme iron intake. However, a link between atherosclerosis (the underlying cause of CVD) and body iron status remains controversial (Corti et al., 1997).

Aston et al. (2012) recently used existing data to model the potential impact of reducing intake of red and processed meat on CHD in the UK population. Their analysis suggested that if those individuals in the highest quintile of processed meat intake were to consume the equivalent intake of those in the lowest quintile, their risk of developing CHD would be reduced by 20.6% in men and 11% in women. However, a similar switch in red meat intake failed to predict any benefit.

While CHD represents the major manifestation of CVD in younger age groups, stroke becomes more prevalent as we age. Thus, in the UK, while strokes account for approximately 5.5% of total deaths in people between the ages of 65 and 74 years, this doubles in the 75+ age group (British Heart Foundation, 2012c). A recent meta-analysis of six prospective studies suggested that for each serving per day increase in fresh red meat,

processed meat, or total red meat consumption, the relative risks (95% CI) of total stroke were 1.11 (1.03 to 1.20), 1.13 (1.03 to 1.24), and 1.11 (1.06 to 1.16), respectively (Kaluza et al., 2012).

Despite some discrepancies between studies, perhaps as a result of the demographics of populations and the range, and type, of meat consumed, in general, it appears that the highest consumers of red meat may be at increased risk of developing CVD. Overall, it appears that processed meats may have a greater adverse impact of CVD risk than lean red meat. The reasons for the differences between red and processed meat remain to be established, but a comparison of red and processed meat in the US diet suggests that processed meats contain similar levels of SFA to red meat but fourfold higher levels of sodium and 50% more non-salt preservatives (Micha et al., 2010). However, nutrient intake from processed meats is likely to vary considerably between countries depending on the types of product that are habitually consumed.

Milk, Dairy Produce, and Cardiovascular Disease

Cows' milk, and products made from it, are established components of the diet of a large proportion of the population of developed countries. The fatty acid composition of such milk is largely governed by the same factors as those described for ruminant meat. One important difference is the considerably greater production of shorter-chain SFA. The typical fatty acid composition of bovine milk is shown in Figure 6. Due to its contribution to total SFA intake, like meat, milk consumption might be predicted to increase CVD risk. However, a recent meta-analysis of prospective cohort studies suggests a significantly reduced, rather than increased, risk of both ischemic heart disease and stroke in those with the highest compared with the lowest milk intakes (Elwood et al., 2010). The authors point out that the data included in their analysis related overwhelmingly to whole milk as opposed to fat-reduced skimmed milk. Based on the existing and limited evidence available, the authors failed to find any specific effects of consumption of either butter or cheese. A more recent meta-analysis of 17 prospective studies appears to support a protective effect of milk intake on overall CVD risk (Soedamah-Muthu et al., 2011). The mechanisms whereby consumption of milk may offer protection from cardiovascular disease remain to be elucidated. However, Elwood et al. (2010) suggest a number of potential factors including antihypertensive effects of calcium and certain peptides released during the digestion of milk protein. It has also been shown recently that dairy calcium may partly offset the cholesterol-raising effect of the SFA in milk, perhaps through the formation of calcium soaps of fatty acids and increased fecal excretion (Lorenzen and Astrup, 2011).

As already mentioned, ruminant milk, and to a lesser extent meat, is a significant source of TFA. There is considerable controversy over the potential impact of these fatty acids on CVD risk. This is largely based on the isomer distribution as partially hydrogenated vegetable oils (**PHVO**) normally contain a wide range of trans isomers of monounsaturated fatty acids (**MUFA**), which differ in the position along the carbon chain of the double bond (Bauman et al., 2006). By contrast, one isomer (vaccenic
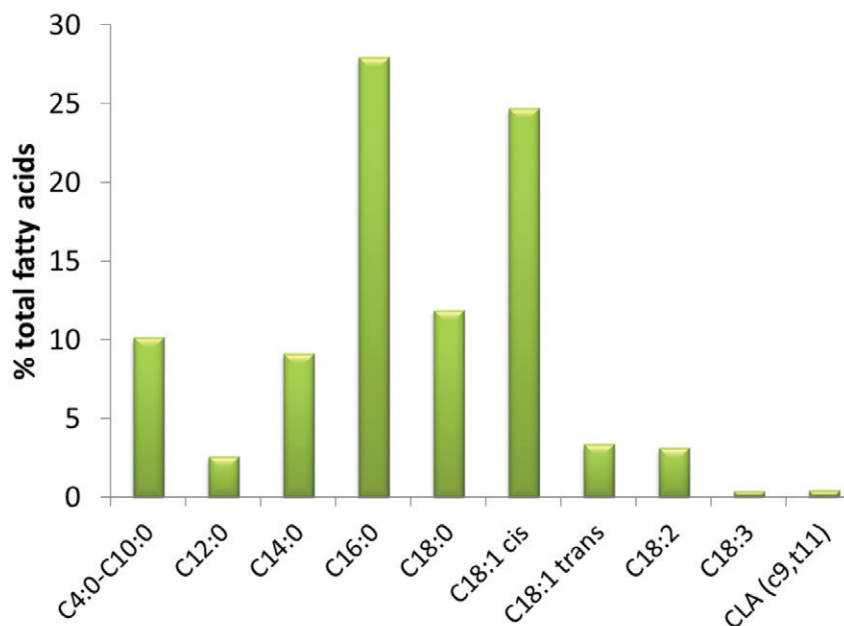
Figure 6. Typical fatty acid composition of bovine milk. Redrawn from data presented by Lock et al. (2005).

acid, or VA, trans11-C18:1) predominates in ruminant products. Vaccenic acid has been shown to be a precursor for the production of the *cis*9, *trans*11 conjugated linoleic acid (**CLA**) isomer, which itself is also found in ruminant milk. Studies, using animal models, have suggested that VA and *cis*9, *trans*11 CLA have anti-atherosclerotic properties (Bauman et al., 2006). A recent meta-analysis of human studies failed to find any significant effect of ruminant TFA on CHD risk, but the authors express caution over the relatively small number of studies available (Bendsen et al., 2011). Another recent review by Gebauer et al. (2011) similarly concluded that there is insufficient high quality human data available to make a firm conclusion. However, the limited evidence available would suggest that while TFA associated with PHVOs almost certainly increase CVD risk, at intake levels seen in a typical Western diet, ruminant TFA are, at worst, neutral.

Animal Products, Obesity, and Type 2 Diabetes

There is overwhelming evidence that eating energy-dense diets, rich in animal products and refined carbohydrate, combined with the sedentary lifestyle adopted by many individuals in developed countries, has resulted in incidences of obesity of almost epidemic proportions. In time, a significant number of obese individuals become insulin resistant and develop the metabolic syndrome (**MetSyn**). The MetSyn represents a cluster of risk factors that predispose the individual to both CVD and type 2 diabetes, including high-plasma triacylglycerol, low-HDL cholesterol, hypertension, and glucose intolerance. Individuals displaying three or more of these risk factors associated with MetSyn are 24 to 29 times more likely to develop type 2 diabetes than those displaying no risk factors (Wilson et al., 2005). In general, animal products are relatively energy dense and, as such, might be expected to be making a major contribution to this problem. However, energy-dense foods, particular those rich in protein, have been associated with increased satiety.

In a recent review of the topic, Gilbert et al. (2011) concluded that the amount of protein in the diet is more important than the source of the protein. There appears to be little doubt that vegetarianism is associated with reduced incidences of obesity than in the omnivorous population (Tonstad et al., 2009) and, as such, a decreased risk of developing MetSyn and type 2 diabetes. This does not, however, mean that meat consumption, per se, increases the risk of developing these conditions. The systematic review by Micha et al. (2010) found that there was no apparent effect of red meat on the incidence of diabetes, but there was an increased risk associated with processed meat. However, a further combined analysis of the Health Professionals Study and the Nurses Heath Study (Pan et al., 2011) and an accompanying meta-analysis including previous studies suggested that both fresh red meat and processed meat were associated with increased risk of developing type 2 diabetes with the effects of the latter being more pronounced. In a qualitative review, Wyness et al. (2011) conclude that "high" consumers of red meat may have a higher risk of type 2 diabetes compared with "low" consumers but suggest further work is required to define the level of intake that may be associated with increased risk (Figure 7).

High intakes of dairy products have been associated with reduced risk of developing MetSyn in a number of studies. For example, in the Caerphilly Prospective Study, the relative risk of men (adjusted for age, energy, social class, and smoking) for developing MetSyn in the highest quartile of milk drinkers was 0.43 ($P = 0.023$) compared with those in the lowest quartile (Elwood et al., 2007). In a recent systematic review of this topic, Crichton et al. (2011) found an inverse relationship between dairy intake and incidence, or prevalence, of MetSyn in 7 out of 13 studies reviewed. However, they expressed caution in drawing any firm conclusion due to the relatively small number of prospective cohort studies performed and the lack of any randomized control trials. In terms of risk of developing type 2 diabetes, Elwood et al. (2010) recently reported an analysis of five cohort studies and estimated an overall reduction in relative risk of 15% in those reporting the highest intake of milk and dairy produce.

Animal Product Consumption and Cancer

A detailed consideration of the link between consumption of animal products and the incidence of various cancers is beyond the expertise of this author. However, at the very least, the association between animal product intake and colorectal and prostate cancer requires some discussion. In 2007, the World Cancer Research Fund and the American Institute of Cancer Research (WCRF/AICR, 2007) judged that there was convincing evidence of a link between consumption of red and processed meat and colorectal cancer. In a recent update, drawing data from 24 prospective studies, Chan et al. (2011) reported that the risk of developing colorectal cancer increased 14% for every 100 g/day increase of total red and processed meats. When assessed separately, both red meat and processed meat were independently associated with increased risk. While, like all cancers, there are multiple genetic and lifestyle risk factors associ-

Figure 7. Research from Pan et al., 2011 found that a high consumption of red meat may lead to a greater risk of type 2 diabetes compared with less consumption (source: flickr. com/tarale).

Figure 8. The consumption of milk and dairy products has been suggested to be inversely associated with the risk of cardiovascular disease, type 2 diabetes, and colorectal cancer (source: flickr.com/ pyth0ns).

ated with the development of colorectal cancer, the evidence in support of avoiding very high intakes of red and/or processed meat appears compelling. Interestingly, consumption of milk and dairy products has been suggested to be inversely associated with the risk of colorectal cancer (Figure 8). A recent systematic review (Aune et al., 2012) reported a nonlinear association between milk and total dairy products and colorectal cancer risk ($P < 0.001$), with the inverse associations appearing to be the strongest at the higher range of intake.

The WCRF/AICR (2007) report also reviewed the evidence for a link between milk and dairy consumption and prostate cancer. Reviewing a variety of cohort, case control, and ecological studies, while acknowledging inconsistencies, they concluded there is limited evidence suggesting that milk and dairy products are a cause of prostate cancer. In a further meta-analysis, Elwood et al. (2008) found a modest (relative risk = 1.06) association between milk and dairy product intake and prostate cancer through analysis of pooled cohort studies. However, Huncharek and Ku-

pelnick (2008) failed to find a relationship in the meta-analysis of either cohort or case control studies.

Conclusions

Meat, milk, and products made from them represent protein and energy-dense foods that are also important sources of certain micronutrients including vitamin B_{12}, calcium, zinc, and bioavailable iron. The emergence of a country's economy is often associated with increased consumption of animal products by the population. In general, this is paralleled by increased longevity and a shift in morbidity and mortality from infectious agents to NCD. Excessive consumption of energy dense, SFA-rich animal products, together with large amounts of refined carbohydrate, often in association with a sedentary lifestyle, almost certainly predisposes the individual to an increased risk of obesity, type 2 diabetes, and CVD. In terms of red meat consumption, the greatest risk appears to be in those that regularly consume more than one portion per day and may be particularly associated with regular consumption of processed, rather than fresh, red meat. Available evidence suggests that milk consumption is associated with relative protection from these diseases. In terms of cancer risk, consumption of very high amounts of red and/or processed meat may be associated with increased risk of developing colorectal cancer. High consumption of milk may actually protect from colorectal cancer but perhaps modestly increase risk of prostate cancer in males. As part of a varied diet, containing a range of fruit, vegetables, and oils rich in unsaturated fatty acids, there is little evidence to link moderate intake of animal products with susceptibility to NCD.

Literature Cited

Aston, L. M., J. N. Smith, and J. W. Powles. 2012. Impact of a reduced red and processed meat dietary pattern on disease risks and greenhouse gas emissions in the UK: A modelling study. BMJ Open 2:e001072. doi:10.1136/bjmopen-2012–001072.

Aune, D., R. Lau, D. S. M. Chan, R. Vieira, D. C. Greenwood, E. Kampman, and T. Norat. 2012. Dairy products and colorectal cancer risk: A systematic review and meta-analysis of cohort studies. Ann. Oncol. 23:37–45.

Bates, B., A. Lennox, and G. Swan. 2010. National diet and nutrition survey. Headline results from year 1 of the rolling programme (2008/2009). Food Standards Agency/Department of Health, London.

Bauman, D. E., A. L. Lock, B. A, Corl, C. Ip, A. M. Salter, and P. W. Parodi. 2006. Milk fatty acids and human health: Potential role of conjugated linoleic acid and trans fatty acids. In: K. Sejrsen, T. Hvelplund, and M. O. Nielsen (ed.) Ruminant physiology: Digestion, metabolism and impact of nutrition on gene expression, immunology and stress, Wageningen Academic Publishers, Wageningen, The Netherlands. p. 529–561.

Bendsen, N. T., R. Christensen, E. M. Bartels, and A. Astrup. 2011. Consumption of industrial and ruminant trans fatty acid and risk of coronary heart disease: A systematic review and meta-analysis of cohort studies. Eur. J. Clin. Nutr. 65:773–783.

Bernstein, A. M., Q. Sun, F. B. Hu, M. J. Stampfer, J.-A. E. Manson, and W. C. Willett. 2010. Major dietary protein sources and risk of coronary heart disease in women. Circulation 122:876–883.

British Heart Foundation. 2012a. Heart statistics. http://www.bhf.org.uk/research/heart-statistics/risk-factors/diet.aspx. Accessed October 13, 2012.

British Heart Foundation 2012b. Heart statistics. http://www.bhf.org.uk/research/statistics/mortality/numbers-dying/time-trends.aspx. Accessed October 13, 2012.

British Heart Foundation 2012c. Heart statistics. http://www.bhf.org.uk/research/statistics/mortality/numbers-dying.aspx. Accessed October 13, 2012.

Chan, D. S. M., R. Lau, D. Aune, R. Vieira, D. C. Greenwood, E. Kampman, and T. Norat. 2011. Red and processed meat and colorectal cancer incidence: Meta-analysis of prospective studies. PLoS ONE 6:E20456. doi:10.1371/journal.pone.0020456.

Corti, M.-C., M. Gaziano, and C. H. Hennekens. 1997. Iron status and risk of cardiovascular disease. Ann. Epidemiol. 7:62–68.

Crichton, G. E., J. Bryan, J. Buckley, and K. J. Murphy. 2011. Dairy consumption and metabolic syndrome: A systematic review of findings and methodological issues. Obes. Rev. 12:E190–e201.

Elwood, P. C., D. I. Givens, A. D. Beswick, A. M. Fehily, J. E. Pickering, and J. Gallacher. 2008. The survival advantage of milk and dairy consumption: An overview of evidence from cohort studies of vascular diseases, diabetes and cancer. J. Am. Coll. Nutr. 27:S723–S734.

Elwood, P. C., J. E. Pickering, and A. M. Fehily. 2007. Milk and dairy consumption, diabetes and the metabolic syndrome: The Caerphilly Prospective Study. J. Epidemiol. Community Health 61:695–698.

Elwood, P. C., J. E. Pickering, D. I. Givens, and J. E. Gallacher. 2010. The consumption of milk and dairy foods and the incidence of vascular disease and diabetes: An overview of the evidence. Lipids 45:925–939.

FAO. 2009. The state of food and agriculture. http://www.fao.org/publications/sofa/en/. Accessed October 13, 2012.

Food Standards Agency. 2010. National diet and nutrition survey 2008/09. http://www.food.gov.uk/science/dietarysurveys/ndnsdocuments/ndns0809year1. Accessed October 13, 2012.

Fox, M. K., K. Reidy, T. Novak, and P. Zeigler. 2006. Sources of energy and nutrients in the diets of infants and toddlers. J. Am. Dietet. Assoc. 106:S28–S42.

Gebauer, S. K., J. M. Chardigny, M. U. Jakobsen, B. Lamarche, A. L. Lock, S. D. Proctor, and D.J. Baer. 2011. Effects of ruminant trans fatty acids on cardiovascular disease and cancer: A comprehensive review of epidemiological, clinical, and mechanistic studies. Adv. Nutr. 2:332–354.

Gilbert, J.-A., N. T. Bendsen, A. Tremblay, and A. Astrup. 2011. Effect of proteins from different sources on body composition. Nutr. Metab. Cardiovasc. Dis. 21:B16–B31.

Hooper, L., C. D. Summerbell, R. Thompson, D. Sills, F. G. Roberts, H. Moore, and G. Davey Smith. 2011. Reduced or modified dietary fat for preventing cardiovascular disease. Cochrane Database of Systematic Reviews 2012, issue 5. Art. no.: CD002137. doi: 10.1002/14651858.CD002137.pub3.

Huncharek, M., and M. J. Kupelnick. 2008. Dairy products, dietary calcium and vitamin D intake as risk factors for prostate cancer: A meta-analysis of 26,769 cases from 45 observational studies. Nutr. Cancer 60:421–441.

Jakobsen, M. U., E .J. O'Reilly, B. L. Heitmann, M. A. Pereira, K. Bälter, G. E. Fraser, U. Goldbourt, G. Hallmans, P. Knekt, S. Liu, D. Speigelman, J. Stevens, J. Virtamo, W. C. Willett, and A. Ascherio. 2009. Major types of dietary fat and risk of coronary heart disease: A pooled analysis of 11 cohort studies. Am. J. Clin. Nutr. 89: 1425–1432.

Kaluza, J., A. Wolk, and S. C. Larsson. 2012. Red meat consumption and risk of stroke: A meta-analysis of prospective studies. Stroke doi: 10.1161/STROKEAHA.112.663286.

Key, T. J., P. N. Appleby, and M. S. Risell. 2006. Health effects of vegetarian and vegan diets. Proc. Nutr. Soc. 65:35–41.

Kliem, K. E., and D. I. Givens. 2011. Dairy products in the food chain: Their impact on health. Annu. Rev. Food Sci. 2:21–36.

Lock, A. L., C. A. M. Horne, D. E. Bauman, and A. M. Salter. 2005. Effect of butter enriched in conjugated linoleic acid (CLA) and vaccenic acid on plasma lipoproteins and tissue fatty acid composition in the cholesterol-fed hamster. J. Nutr. 135:1934–1939.

Lorenzen, J. K., and A. Astrup. 2011. Dairy calcium intake modifies responsiveness of fat metabolism and blood lipids to a high fat diet. Brit. J. Nutr. 105:1823–1831.

Mensink, R. P., P. L. Zock, A. D. M. Kester, and M. B. Katan. 2003. 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. 77:1146–1155.

Micha, R., S. K. Wallace, and D. Mozaffariam. 2010. Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: A systematic review and meta-analysis. Circulation 121:2271–2283.

Mozaffarian, D., R. Micha, and S. Wallace. 2010. Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: A systematic review and meta-analysis of randomized controlled trials. PLoS Med. 7(3): e1000252. doi:10.1371/journal.pmed.1000252.

Pan, A., Q. Sun, A. M. Bernstein, M. B. Schulze, J.-A., E. Manson, W. C. Willett, and F. B. Hu. 2011. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. Am. J. Clin. Nutr. 201:1088–1096.

Pan, A., Q. Sun, A.M. Bernstein, M.B. Schulze, J-A. E. Manson, M.J. Sampfer, W.C. Willett and F.B. Hu. 2012. Red meat consumption and mortality. Arch. Intern. Med. 172: 555–563.

Population Reference Bureau. 2007. 2007 world population data sheet. http://www.prb.org/Publications/Datasheets/2007/2007WorldPopulationDataSheet.aspx. Accessed October 13, 2012.

Salter, A. M. 2011. Dietary fatty acids and cardiovascular disease. Animal 11:1–9.

Siri-Tarino, P. W., Q. Sun, F. B. Hu, and R. M. Krauss. 2010. Meta-analysis of prospective cohort studies evaluating the association of saturated fat with cardiovascular disease. Am. J. Clin. Nutr. 91:535–546.

Skeaff, C. M., and J. Miller. 2009. Dietary fat and coronary heart disease: Summary of evidence from prospective cohort and randomised controlled trials. Ann. Nutr. Metab. 55:173–201.

Soedamah-Muthu, S. S., E. L. Ding, W. K. Al-Delaimy, F. B. Hu, M. F. Engberink, W. C. Willett, and J. M. Geleijnse. 2011. Milk and dairy consumption and incidence of cardiovascular diseases and all-cause mortality: Dose–response meta-analysis of prospective cohort studies. Am. J. Clin. Nutr. 93:158–171.

Tonstad, S., T. Butler, R. Yan, and G. E. Fraser. 2009. Type of vegetarian diet, body weight, and prevalence of type 2 diabetes. Diabetes Care 32:791–796.

Unal, B., J. A. Critchley, and S. Capewell. 2004. Explaining the decline in coronary heart disease mortality in England and Wales between 1981 and 2000. Circulation 109:1101–1107.

WCRF/AICR. 2007. Food, nutrition, physical activity, and the prevention of cancer: A global perspective. WCRF, London, and AICR, Washington, DC.

WHO. 2011. Global status report on non-communicable diseases. 2010. WHO, Geneva, Switzerland.

WHO. 2012. Global Health Observatory (GHO). http://www.who.int/gho/countries/en/. Accessed October 13, 2012.

Wilson, P. W., R. B. D'Agostino, H. Parise, L. Sullivan, and J. B. Meigs. 2005. Metabolic syndrome as a precursor of cardiovascular disease and type 2 diabetes mellitus. Circulation 112:3066–3072.

Wyness L., E. Weichselbaum, A. O'Connor, E. B. Williams, B. Benelam, H. Riley, and S. Stamnner. 2011. Red meat in the diet: An update. Nutr. Bull. 36:34–77.

About the Author

Andrew Salter is Professor of Nutritional Biochemistry and Head of the Division of Nutritional Sciences in the School of Biosciences at the University of Nottingham, UK. He is involved in teaching undergraduate and postgraduate students with interests in both animal and human nutrition. Having completed a Ph.D. at Guy's Hospital Medical School (University of London) looking at lipoprotein metabolism and cardiovascular disease risk in Diabetes Mellitus, his research career has centered on nutritional and hormonal regulation of lipid and lipoprotein metabolism. He has also had a long term interest in factors regulating the fatty acid composition of milk and meat.

Correspondence: andrew.salter@nottingham.ac.uk