Aspects of Applied Biology 79, 2006
What will organic farming deliver? COR 2006

Linking livestock production to human health – creating sustainability through farming

By J C MACRAE

Rowett Research Institute, Bucksburn, Aberdeen AB21 9SB

Summary

The main dietary risk factors associated with the early onset of the non-communicable diseases (cardiovascular disease (CVD) and cancer) would seem to be the over-consumption of dietary lipids and the under-consumption of dietary micronutrients. Consumer preference for lower fat, higher protein diets and for less saturated and more polyunsaturated fat has been around for a number of years. However, more recent clinical studies have indicated beneficial (anti-inflammatory) effects of increasing the omega-3: omega-6 ratio of dietary PUFA and potential anti-cancer and -heart disease effects of increasing consumption of conjugated linoleic acid (CLA). These factors are considered in relation to the fatty acid composition of milk and meat derived from organic systems. Animal products are also important sources of several micronutrients and recent information of the health benefits of increasing dietary selenium and iron are considered in relation to promoting organic animal products to the health-conscious consumer.

Introduction

Human foodstuffs derived from organic systems are usually marketed in terms of their 'wholesomeness', their lower levels of pesticide residues, nitrates and nitrites and arguably higher levels of vitamin C, total sugars and flavonoids (fruit and vegetables) and their lack of antibiotic residues (meat, milk and eggs). These concepts presently sustain a price premium to offset the lower production potential of organic systems, but it is difficult to find definitive evidence that such attributes are indeed beneficial in terms of human health and reduced disease risk. In contrast, there is a vast literature linking the inappropriate consumption of specific nutrients within food and the risk of developing Coronary Heart Disease (CHD) and cancer. It might be useful therefore to examine if/how this information might be translated into more substantial arguments that could help in the longer-term promotion of organically-derived animal products to the health-conscious consumer.

Fats

Saturated and polyunsaturated fats(PUFA)

There is a history of concern about the lipid content of foodstuffs, with 'animal (especially ruminant saturated) fats' being viewed with particular suspicion. In the 1960/70s, epidemiologists identified strong relationships between the proportion of the dietary calories consumed as saturated fat and the incidence of CHD and colon, prostrate and breast cancer. Saturated fat was shown to increase levels of cholesterol in the circulating serum lipoproteins, whereas polyunsaturated fats (PUFA) seemingly modulate these rises in risk factor. This led to recommendations for a reduction of saturated fat in the diet and, for example to UK consumers switching from full-fat to semi-skimmed milk and fat-trimmed meat.

Omega-3 PUFA

In the early 1990s, research started to show that the different PUFA were not all equally beneficial. Inflammatory responses are important components in the development of CHD and cancer and immunologists identified that the omega-6 (n-6) PUFA are less beneficial than the omega-3 (n-3) PUFA (Gibney & Hunter 1992). This relates to the ability of the n-3 PUFA to modulate the pro-inflammatory eicosanoids which are generated during the post-absorptive metabolism of the n-6 PUFA. Present recommendations are to increase the intake of n-3 PUFA towards a dietary optimum n-3:n-6 PUFA ratio of 0.4-0.5. Most human foodstuffs have a ratio nearer to 0.1-0.2, hence the health benefits of fish oil products which contain high levels of longer chain n-3 PUFA.

Fish oils are an abundant source of the longer-chain n-3 PUFA because of the high (n-3) linolenic acid content of chloroplast lipids in marine phytoplankton, the basic photosynthetic building block of the Marine Food Web. Chloroplasts are of course a crucial component of fresh forages also and recent research has started to identify substantial increases in the n-3:n-6 PUFA ratio in the lipids of animals fed fresh forages rather than concentrates (see Dewhurst *et al*., 2003). Given the high dependency on forages for organic dairy and beef production it is perhaps not surprising that one recent study indicated that milk leaving the farm gate of organic dairy farms has a consistently higher n-3:n-6 PUFA ratio than that leaving conventional farms, particularly during the winter months (Ellis *et al*., 2006).

Conjugated linoleic acids (CLA)

The n-3 PUFA were the interest of clinicians/human nutritionists during the 1990s, but over the last 5 years equal, if not more, attention has been directed at CLA. A plethora of animal studies have reported that CLA can reduce the severity of cholesterol-induced CHD (Lee *et al.,* 1994) and carcinogen-induced mammary tumours (Ip *et al*., 2001). Recent studies at the Rowett would suggest that CLA alter inflammatory mechanisms by modulating the transcription of adhesion molecules (which lead on to plaque formation) in endothelial cells (Goua *et al*., 2004).

The CLA are very much an attribute of ruminant products, being formed as an intermediary metabolite in the biohydrogenation of C18:2 (unsaturated) linoleic acid to 18:0 (saturated) stearic acid during rumen fermentation. Hence, levels of CLA in milk, cheese, butter, lamb and beef (4-7 mg/g total FA) are considerably higher than in non-ruminant products (chicken, pork, fish, olives; < 1 mg g^{-1}). Furthermore, whilst there are a number of different isomers of CLA, ruminant products contain mainly the *cis*-9, *trans-11* form which seems to be the most potent in terms of anti-inflammatory properties.

These ‘typical’ levels would not provide sufficient CLA intake per day to off-set inflammation in humans (unless you consumed over 3.5 kg of cheese per day). However, importantly from the organic farming perspective, cis-9, trans-11 CLA levels in milk (Dhiman *et al*., 1999) and meat (Poulson *et al.,* 2004) from animals grazing on pasture (18-22 mg g^{-1} total fat) can be several fold higher than from more intensively farmed animals. Furthermore, supplementation with linseed or sunflower oil has been demonstrated to give addition responses (de Wit *et al*., 2006).

Micronutrients

Whilst clinicians and human nutritionists are now advocating increased intake of n-3 PUFA, one of the underlying mechanisms associated with the onset of CHD and cancer is disruption of normal cellular processes. In this respect, lipid oxidation, particularly of the PUFA, is a major stressor and to modulate these processes cells depend on antioxidants such as vitamin E and a number of glutathione peroxidases (GPX).

Selenium

The genes that transcribe GPX are amongst some 25 selenoproteins genes in the human genome. It is not surprising therefore that epidemiological studies have inversely related the availability of selenium (Se) in the human diet (Se levels in blood) with the incidence of CHD and cancer. Inadequate selenium intake has been linked also with impaired thyroid metabolism, reduced response to viral infection, infertility and, in more serious situations, cardio- and skeletal-myopothies. Recent evidence that daily selenium supplementation can boost the immune system (Broome *et al*., 2004) as well as helping to control tissue oxidative damage would further support the importance of selenium in promoting good health.

Achieving adequate dietary selenium intakes in the UK can be a problem because of the low selenium status of our soils. Indeed, one concern for clinicians over the last 10–15 years has been the substantial reduction in daily Se intake that has occurred following the decision to switch from selenium-rich high-protein North American wheat to lower-Se UK and European wheat for flour making in the mid -1980's. The volcanic and sandy soils across major sectors of the UK have had a lot of their Se leached out, leading to low levels of Se in cereals, fruit and vegetables, and as a result, the daily intake of Se in the UK population (approx. 35µ day^{-1}, see FSA, 2002) is less than half of that in the USA (80-100 µ day^{-1}).

However, this area of preventive nutrition may need careful consideration in terms of promoting 'organic sector' animal products. The Se content of typical animal products in the UK diet (eg red meat and poultry 100 & 160 µg kg^{-1} respectively and particularly liver and kidney > 400 µg kg^{-1}), are considerably higher than in plant components (fruit and vegetables < 10 µg kg^{-1}; cereals 20–25 and bread made from UK & European wheats 50-55 µg kg^{-1}; see FSA, 2002), but the reason for this goes back to the fact that Se deficiency in farm animals has been well recognised for many years and, as a result, inorganic Se has been included at levels of 15–20 mg kg^{-1} routinely in mineral supplements given to conventionally-reared farm livestock since the late 1970s. These supplements are not part of 'organic' systems where seaweed meal, with a Se content of < 1 mg kg^{-1}, would be a typical supplement for dairy cows.

The situation could be addressed, either by addition of selenate to soil where any signs of Se-deficiency in the animals can be demonstrated, or by the use of so-called 'organic' selenium supplements (high-Se yeast) that can, reportedly, double the selenium content of meat and offal in finishing cattle (Richards & Loveday, 2004) and increase the Se content of milk by up to 12-fold (Heard *et al*., 2004). However, the economics of such supplementation would need careful consideration relative to the premium the consumer might pay for the perceived health benefit.

Iron

Clinical attention has been focussed recently on the problems associated with low iron intake during pregnancy. Across Europe as many as one in five pregnant women are clinically anaemic and many more suffer from marginal iron deficiency. If this anaemia is not corrected there is an increased risk of poor pregnancy outcome, premature delivery and/or low birth weight. In addition the new-born baby has a higher risk of developing cardiovascular disease or non-insulin dependent diabetes later in life. Consequently, pregnant women with anaemia are always prescribed (inorganic) iron supplements, but compliance rates are reportedly low due to unpleasant side effects (e.g. gastric upset, nausea and constipation).

The basic problem with inorganic iron supplements is one of bioavailability. Less than 10% of the ingested iron, (or, indeed, the non-haem iron of most plant foodstuffs) is absorbed from the gastrointestinal tract. In comparison, haem iron, (i.e. the iron bound up in the porphyrin ring structures of haemoglobin and myoglobin) present in meat and fish, has a much higher bioavailability (20–30%) (Roughead & Hunt, 2000). Given the clinical problems referred to above and the experimental information from rodent models linking iron deficiency in pregnancy and the subsequent development of hypertension problems in the growing off-spring (Gambling *et al*., 2003), there would appear to be considerable potential for promoting meat as a means of alleviating anaemia.

Here, the fact that organic beef production is generally based on quality beef breeds may provide a marketing advantage. Maltin *et al*. (2001) reported that taste panel assessment of higher meat tenderness scores in Aberdeen Angus correlated with the greater area and frequency of slow twitch oxidative fibre in the muscle of these cattle. The myoglobin content of slow twitch fibres is higher than that of fast twitch fibres. It might be possible therefore to argue that quality (organically-reared) beef is an ideal way of delivering bioavailable iron for the alleviation of anaemia, not just during pregnancy, but through other periods of high iron requirement such as adolescence and menstruation in women.

Vitamins and other micronutrients

There are a number of vitamins which are essential for human health that are either only available or are much more bioavailable from animal products. Bielalski (2005), in reviewing the importance of meat in the human diet, identified that, particularly for the elderly, animal products are an important source of the vitamins A, B_1, B_2, B_6 B_{12} (which of course is only found in animal and fish products) D, E and folate. Milk is also a ready source of vitamins A, D, E and K. However, these are all fat-soluble and so the delivery of them in liquid milk has reduced over recent years as consumers have switched to semi-skimmed and skimmed milk consumption. At times when micronutrient requirements are increased (e.g. pregnancy) vitamin D, folic acid and zinc as well as iron (see above) status may be compromised without meat in the diet.

Conclusion

Whilst the marketing of organic produce on the basis of reduced pesticide and/or antibiotic residues seems a perfectly valid strategy, the economics of the NHS would point to CHD and cancer as the real 'diet and health' issues. These are predominantly problems of the middle-aged and elderly, where normal homeostatic mechanisms start to breakdown and the immune system starts to lose some of its former efficiency. It is perhaps time therefore for the organic sector to consider promoting its products not just in terms of reduced contaminants, but in terms of specific positive health benefits of the type identified in this paper.

References

Biesalski H-K. 2005. *Meat Science* **70**:509–524.

Broome C S, McArdle F, Kyle J A M, Andrews F, Lowe N M, Hart C A, Arthur J R, Jackson M J. 2004. *American Journal of Clinical Nutrition* **80**:154–162.

Dewhurst R J, Scollan N D, Lee M R F, Ougham H J, Humphrey M O. 2003. *Proceedings of the Nutrition Society* **62**:329–336.

De Wit J, Wagenar J P, De Vries, Baars T. 2006. see http:// www.orgprints.org/joc2006.php theme **9**: 7320.

Dhiman T R, Anand G R, Satter L D, Pariza M W. 1999. *Journal of Dairy Science* **82**: 2146–2156.

Ellis K A, Innocent G, Grove-White D, Cripps P, McLean W G, Howard C V, Mihm M. 2006. see http:// www.orgprints.org/joc2006.php theme **9**:7082.

FSA. 2002. see http:// www.foodstandards.gov.uk/multimedia/pdfs/selenium.pdf .

Gambling L, Dunford S, Wallace D I, Zuur G, Solanky N, Srai S K, McArdle H J. 2003. *Journal of Physiology* **552**:603–610.

Gibney M J, Hunter B. 1993. *European Journal of Clinical Nutrition* **47**:255–259.

Goua M, Sneddon A A, Mulgrew S, Wahle K W J. 2004. *Chemical Physiology of Lipids* **130**:

38–38.
Heard J W, Walker G P, Royle P J, McIntosh G H, Doyle P T. 2004. *The Australian Journal of Dairy Technology* **59**:199–203.
Ip C, Dong Y, Thompson H J, Bauman D E, Ip M M. 2001. *Nutrition Cancer* **39**:233–238.
Lee K N, Kritchevsky D, Pariza M W. 1994. *Artherosclerosis* **108**:19–25.
Maltin C A, Lobley G E, Grant C M, Miller L A, Kyle D, Horgan G W, Matthews K R, Sinclair K D. 2001. *Animal Science* **72**:279–287.
Poulson C S, Dhiman T R, Ure A L, Cornforth D, Olson K C. 2004. *Livestock Production Science* **91**:117–128.
Richards C J, Loveday H D. 2004. In *Nutritional Biotechnology in the Feed and Food Industries*, pp. 211–220. Eds T P Lyons and K A Jacques. UK: Nottingham University Press.
Roughead R K, Hunt J R. 2000. *American Journal of Clinical. Nutrition* **72**:982–998.