COMPASSION
in world farming

NUTRITIONAL BENEFITS OF HIGHER WELFARE ANIMAL PRODUCTS

CONTENTS

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EXECUTIVE SUMMARY

One of the main reasons cited by consumers for purchasing higher-welfare animal products is a perception that they are healthier. If this perception is true, choosing higher-welfare animal products over intensively-produced animal products could be expected to have a beneficial effect on consumers' health, with potential implications for dietary advice and opportunities for the marketing of higher-welfare animal products on the basis of nutritional advantages.

Conventional production systems typically involve permanent indoor housing and the use of livestock breeds selected for high productivity. The former may restrict opportunities for exercise and behavioural expression, whilst the latter is associated with a number of production-related conditions that may cause serious animal health and welfare problems. In general, extensive farming systems are considered to have the potential for higher animal welfare than intensive systems. Animal products produced in extensive systems that offer greater opportunities for exercise and behavioural expression (e.g. pasture-based, free-range and organic) and/or from less productive breeds (e.g. slower-growing meat chickens) may have nutritional advantages as a result of, for example, the consumption of fresh forage and greater physical activity, altering the quality of the meat, milk and eggs produced by these animals.

A literature review was conducted in order to examine the evidence for a range of nutritional benefits of higher-welfare animal products. The studies selected compared an extensive production system (free-range, organic or other pasture-based system) with an intensive production system (cage, indoor or feedlot system). For chicken, studies were also included that compared slower-growing breeds with conventional fast-growing breeds.

For salmon and trout, data were not available to compare organically-farmed fish with intensively-farmed fish. Studies comparing wild-caught fish with intensively-farmed fish were therefore selected. Despite serious welfare concerns regarding common methods of capture, handling and processing of wild-caught fish, wild-caught fish are considered to be the higher welfare option in this study. Farmed salmon and trout are not only subjected to prolonged confinement, but require large numbers of wild-caught fish, subjected to inhumane capture, handling and processing, in order to produce their feed.

Comparative data were available in the scientific literature to allow an analysis of fat content, fat composition, protein content, levels of antioxidants such as vitamin E and beta-carotene, and iron content across a range of species and products. In general, protein content and the overall proportions of saturated and unsaturated fatty acids did not differ consistently between higher and lower-welfare systems; data are therefore not presented. Significant differences were however found in the proportions of omega-3 and omega-6 polyunsaturated fatty acids, which are relevant to human health; data are therefore presented. Modern western diets are often deficient in omega-3 fatty acids and have excessive amounts of omega-6 fatty acids relative to omega-3. Additionally, an adequate intake of long-chain (≥20 carbon atoms) omega-3 fatty acids is important for brain and heart health, particularly DHA (docosahexaenoic acid) as its synthesis from shorter chain omega-3 within the body is believed to be limited.

For most species, studies published since 2000 were included. However, fewer studies were available for eggs and fish, so studies published since 1990 were included for these. Studies with very small sample sizes, or not published in English, were excluded. Studies (or data within a study) were also excluded where animals in one or other of the systems compared were supplemented with additional quantities of any of the nutrients of interest.

Lamb

There are no consistent differences in total fat content between lamb from pasture-based and intensive systems. However, pasture-reared lamb has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with intensively-reared lamb. Choosing pasture-reared lamb over intensively-reared lamb would be expected to make a significant contribution to meeting nutritional requirements for long-chain omega-3 fatty acids. This has been demonstrated in human trials, where an increase in long-chain omega-3 fatty acids in blood plasma and platelets was evident following consumption of pasture-reared beef and lamb as opposed to intensively-reared beef and lamb. In Australia, consumption of beef and lamb from predominantly grass-fed animals is estimated to contribute 28% of total dietary intake of long-chain omega-3.

No data were available to compare levels of antioxidants or iron between intensively-reared and pasture-reared lamb.

Beef

Pasture-reared beef contains between 25% and 50% less fat than intensively-reared beef and has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with intensively-reared beef. Choosing pasture-reared beef over intensively-reared beef would be expected to make a significant contribution to meeting nutritional requirements for long-chain omega-3 fatty acids, as demonstrated in human trials and consumption data from Australia.

Pasture-reared beef contains more vitamin E than intensively-reared beef, with up to 4% of the adult RDA in a 100g serving. Pasture-reared beef also contains more beta-carotene than intensively-reared beef, although the amounts are small (equivalent to less than 1% of the adult RDA for vitamin A in a 100g serving). No data were available to compare levels of iron between intensively-reared and pasture-reared beef.

Milk

There are no consistent differences in total fat content between milk from pasture-based and intensive systems. However, milk from pasture-based systems has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with milk from intensive systems. The amounts would be expected to make only a relatively minor contribution to dietary intake of omega-3 and the omega-6 to omega-3 ratio is relatively low in all systems.

Milk from pasture-based systems contains more vitamin E than milk from intensive systems, although the amounts are small (less than 1% of the adult RDA in a 100ml serving). Milk from pasture-based systems also contains more beta-carotene than milk from intensive systems, but again the amounts are small (equivalent to less than 1.5% of the adult RDA for vitamin A in a 100ml serving). No data were available to compare levels of iron between milk from intensive and pasture-based systems.

Pig meat

There are no consistent differences in total fat content between pig meat from free-range/organic systems and intensive systems. However, pig meat from free-range and organic systems has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with pig meat from intensive systems. The amounts would be expected to make only a relatively minor contribution to dietary intake of omega-3 and the omega-6 to omega-3 ratio is relatively high in all systems. Data from Australia indicate pork contributes around 4% of the long-chain omega-3 intake.

Free-range pig meat contains more vitamin E than intensively-reared pig meat, with up to 5% of the adult RDA in a 100g serving. Free-range pig meat also contains more iron than intensively-reared pig meat, with up to 3.5% of the adult RDA in a 100g serving.

Chicken meat

Both rearing system and breed significantly influence the fat content of chicken meat. Free-range and organic chicken meat often contains less fat than intensively-reared chicken meat, in some cases as much as 50% less. Meat from slower-growing chicken breeds also contains less fat than fast-growing breeds: Generally around 10-30% less for medium-growing strains and around 20-65% less for slow-growing strains.

Free-range and organic chicken meat generally has a higher proportion of omega-3 fatty acids compared with intensively-reared chicken meat, with a similar ratio of omega-6 to omega-3. Similarly, chicken meat from medium-growing strains generally has a higher proportion of omega-3 fatty acids compared with fast-growing strains, with a similar ratio of omega-6 to omega-3. The meat from very slow-growing layer strains (those selected for egg production) has a significantly higher proportion of omega-3 compared with fast- and medium-growing broiler strains (those selected for rapid growth). The breast meat of layer strains also has a more favourable (lower) ratio of omega-6 to omega-3 and is particularly rich in long-chain omega-3, including DHA. Choosing higher-welfare (free-range/organic and slower-growing) chicken over intensively-reared fast-growing chicken would be expected to make a significant contribution to meeting nutritional requirements for long-chain omega-3 fatty acids. Data from Australia indicate consumption of chicken contributes an estimated 10% of total dietary intake of long-chain omega-3.

Based on the limited data available, utilising the males of layer breeds for meat production would be expected to produce meat with significantly higher levels of long-chain omega-3. It is standard practice, however, to kill these male chicks post hatching as they are generally considered uneconomic to rear for meat. Creating a premium market for these birds based on the nutritional qualities of the meat would be highly desirable from an ethical point of view, given the hundreds of millions of male layer chicks killed post hatching in the EU every year.

Levels of vitamin E are higher in the meat of slower-growing strains compared with fast-growing strains, although the differences are relatively small. Chicken meat from slower-growing strains and from birds reared organically contains more iron than meat from fast-growing strains and birds reared intensively, with higher welfare options providing around 5-6% of the adult RDA in a 100g serving.

Eggs

There are no consistent differences in total fat content between eggs from free-range/organic systems and battery cage systems. However, free-range and organic eggs generally have a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 compared with battery cage eggs. Some free-range eggs are a particularly rich source of long-chain omega-3, including DHA. Choosing free-range eggs over battery eggs would be expected to make a significant contribution to meeting nutritional requirements for long-chain omega-3 fatty acids.

Free-range eggs often contain more antioxidants (vitamin E, beta-carotene and lutein) compared with battery cage eggs and are a rich source of vitamin E, providing around 25% of the adult RDA in a 100g (2 eggs) serving. No data were available to compare levels of iron between free-range/organic and battery cage eggs.

Salmon and trout

Wild salmon generally contains between 40% and 60% less fat than farmed salmon, with a similar proportion of omega-3 fatty acids. Wild trout generally contains between 25% and 80% less fat than farmed trout and contains a higher proportion of omega-3 fatty acids. Both wild and farmed salmon and trout contain a high proportion of omega-3 fatty acids, including DHA, and can make a substantial contribution to meeting nutritional requirements for long-chain omega-3 fatty acids. However, wild salmon and trout have a lower ratio of omega-6 to omega-3 fatty acids compared with farmed salmon and trout, which may be beneficial in contributing to a more balanced ratio of these fatty acids in the diet.

Wild trout contains more iron than farmed trout, with around 5% of the adult RDA in a 100g serving. No data were available to compare levels of antioxidants between wild and farmed fish.

Higher-welfare animal products were shown to have a number of nutritional benefits over intensively-reared animal products. Excessive fat consumption can contribute to weight gain and associated health problems. Higher-welfare animal products are often significantly lower in fat than equivalent products from intensively-reared animals. This is true of pasture-reared beef, free-range and organic chicken and chicken of slower-growing breeds, and wild salmon and trout.

Choosing higher-welfare animal products over intensively-reared animal products would be expected to be beneficial in reducing dietary intake of fat, including saturated fat.

Modern western diets are often deficient in omega-3 fatty acids and have excessive amounts of omega-6 fatty acids relative to the amount of omega-3. An adequate intake of long-chain (≥20 carbon atoms) omega-3 fatty acids is particularly important for brain and heart health. Compared with intensively-farmed animal products, higher-welfare animal products typically have higher levels of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids. Wild salmon and trout, pasture-reared lamb and beef, chicken meat from slow-growing layer-type strains and some free-range eggs are particularly beneficial in this respect.

Choosing higher-welfare animal products over intensively-reared animal products would be expected to make a substantial contribution to meeting dietary requirements for long-chain omega-3 fatty acids and achieving a more balanced intake of omega-6 and omega-3 fatty acids.

Higher-welfare animal products often contain higher levels of antioxidants, such as vitamin E and beta-carotene, and higher levels of iron, compared with intensively-produced animal products.

Choosing higher-welfare animal products over intensively-reared animal products would be expected to make a moderate contribution to meeting dietary requirements for vitamin E and iron.

1. Introduction

High standards of farm animal welfare and extensive production systems are associated in consumers' minds with healthy, high quality products. When asked to choose up to three reasons why European consumers buy products produced in a more animal-friendly way, the top answer, given by half (51%) the respondents, was that they perceived these products to be healthier (Eurobarometer, 2007).

If this perception is true, choosing higher-welfare animal products over intensively-produced animal products could be expected to have a beneficial effect on consumers' health, with potential implications for dietary advice and opportunities for the marketing of higher-welfare animal products on the basis of nutritional advantages.

Conventional production systems typically involve permanent indoor housing and the use of livestock breeds selected for high productivity. The former may restrict opportunities for exercise and behavioural expression, whilst the latter is associated with a number of production-related conditions that may cause serious animal health and welfare problems. Animal products produced in systems that offer greater opportunities for exercise and behavioural expression (e.g. pasture-based, free-range and organic) and/or from less productive breeds (e.g. slower-growing meat chickens) may have nutritional advantages as a result of, for example, the consumption of fresh forage and greater physical activity. This report examines the evidence for a range of nutritional benefits of higher-welfare animal products, using extensive production as an indication of farming systems with the potential for higher animal welfare.

2. Welfare potential of the production systems being compared

Welfare can be poor in any farming system if stockmanship is poor. However, systems vary in their potential to provide good welfare. Even if stockmanship is good, welfare is likely to be poor in confinement systems that severely restrict freedom of movement or in barren overcrowded conditions that limit behavioural expression.

A farming system that provides for behavioural freedom without compromising health can be described as having high welfare potential. Major concerns for animal welfare arise from farming systems with low welfare potential, i.e. those that fail to meet the behavioural and physical needs of the animal and are therefore likely to cause suffering. The ability of a system to provide good welfare is determined by factors that are built into the system. Building blocks of a good system include the provision of adequate living space and access to resources to meet the needs of the animals.

2.1 Lamb

For lamb, studies were selected that compared a pasture-based system (100% pasture and/or maternal milk with dams also kept at pasture) with an intensive system (finishing indoors or in a feedlot with a ration based on concentrate and cut/conserved forage permitted but no access to pasture).

Sheep who are confined and fed a diet based on concentrate may develop abnormal behaviours such as wool biting (biting and eating the wool of other sheep), considered to be redirected foraging behaviour in sheep deprived of adequate levels of activity or oral stimulus (Vasseur *et al*, 2006): aggression can also be a problem in housed sheep.

With good stockmanship, pasture-based systems can offer sheep a high standard of welfare, providing opportunities for exercise and expression of a wide repertoire of natural behaviours, including foraging and social behaviour. Lambs reared at pasture often benefit from being kept with their dam for an extended period.

2.2 Beef

For beef, studies were selected that compared a pasture-based system (cattle kept at pasture with some supplementation of cut/conserved forage permitted where necessary but no feeding of concentrate) with an intensive system (finishing indoors or in a feedlot with a ration based on concentrate and cut/conserved forage permitted but no access to pasture).

Confined cattle may show increased aggression and abnormal behaviours, such as tongue-rolling and licking of pen fixtures and other cattle, especially when kept in barren systems with slatted floors and high stocking densities (Broom and Fraser, 2007). Such housing conditions are also associated with an increased incidence of lameness, bruising and other injuries (*Ibid.*).

As with sheep, pasture-based systems can offer cattle freedom of movement and behavioural expression and the cow-calf relationship is often maintained over an extended period.

2.3 Milk

For milk, studies were selected that compared an organic or other pasture-based system (cows kept at pasture during the grazing season; supplementation with cut/conserved forage and some concentrate is permitted and cows may be housed over winter) with an intensive system (cows kept largely or entirely indoors and fed a total mixed ration or concentrate and cut/ conserved forage and may also involve some grazing; or conventional retail or bulk milk, which may include milk from a range of systems).

Systems where dairy cows are housed for most or all of the year are associated with a higher risk of health problems and physical injuries. For example, studies in the UK indicate the risk of lameness is doubled when cows are kept permanently indoors compared with cows in grazing herds (Barker *et al*, 2010, Haskell *et al*, 2006).

Pasture-based systems offer cows freedom of movement and opportunities for natural behaviour and there are a large number of studies showing that cows kept on pasture are healthier (EFSA, 2009).

2.4 Pig meat

For pig meat, studies were selected that compared a free-range or organic system with an intensive indoor system.

Intensively-reared pigs are housed in indoor pens, often with high stocking densities and barren slatted floors. In the absence of appropriate substrate to explore, pigs redirect their exploratory behaviour towards pen structures and other pigs, which can lead to damaging behaviours like ear and tail biting. These abnormal behaviours, which cause pain and injury, are a sign that the behavioural needs of pigs are not met (EFSA, 2007). As a result, many intensively-reared pigs have their tails docked and teeth clipped without anaesthetic, despite an EU ban on the routine use of these mutilations. Some higher-welfare indoor systems address this problem by providing enrichment such as straw and higher space allowances.

In free-range and organic systems, pigs have access to the outdoors where they have opportunities for exercise, foraging, rooting and exploration. Straw-bedded huts or arcs are provided for shelter.

2.5 Chicken meat

For chicken, studies were selected that compared a free-range or organic system with an indoor system (including intensive, extensive and experimental indoor systems) and/or slower-growing genotypes with conventional fast-growing genotypes. For the purposes of this study, the growth rates of the various chicken genotypes were classified as follows:

- Fast-growing broiler-type: Typically reach slaughter weight (≥2kg) in ≤40 days (e.g. Ross 208, Ross 308, Cobb 700, Hybro-G);
- Medium-growing broiler-type: Typically reach slaughter weight (≥2kg) in 49-84 days (e.g. Naked-Neck Kabir, ISA JA57/SA77N.fr Rouge, RedBro Cou Nu/M, Prelux-Bro);
- Slow-growing dual-purpose or layer-type: Typically reach slaughter weight (~2kg) in >100 days (e.g. Dual-purpose: Robusta Maculata, Gushi (Chinese Local Chicken); Layer-type: Brown Classic Lohmann, ISA Brown).

Most broiler (meat) chickens are reared at high stocking densities in large closed sheds. The overcrowded conditions can restrict the birds' ability to move around freely and express natural behaviour.

Broiler chickens are bred for fast growth, efficient feed conversion and large breast meat yield. Standard commercial broilers now reach a slaughter weight of 2 to 2.5kg in 35-40 days compared with 12 weeks 30 years ago. They grow at average rates of 55 to 63g/d and can reach rates of 100g/d near slaughter age. This rapid growth and large breast conformation has resulted in serious health problems and limits the behavioural and physical activity levels of the birds. At least a quarter of commercially-reared fast-growing broilers are likely to experience pain as a result of lameness (Knowles *et al*, 2008; Danbury *et al*, 2000). Fast-growing broilers also suffer from a number of cardiovascular disorders, which can cause sudden death and are responsible for a major portion of flock mortality (Julian, 2005).

Chickens in free-range and organic systems are reared at lower stocking densities and have access to the outdoors. They are reared to higher slaughter ages and are usually moderately slower-growing breeds. Extensive indoor systems use significantly lower stocking densities than conventional systems, usually provide enrichment to encourage greater physical activity, and often use moderately slower-growing breeds.

2.6 Eggs

For eggs, studies were selected that compared a free-range or organic system with a battery cage system.

In conventional battery cages, each hen has just 550cm^2 of floor space, an area less than an A4 sheet of typing paper. They are unable to stretch, flap their wings or turn around without difficulty, and are prevented from carrying out most species-specific patterns of behaviour, including foraging, perching, dustbathing and laying their eggs in a nest. Conventional battery cages are prohibited across the EU from 2012. However, “enriched” cages continue to be permitted. These cages contain a nest, perch and a small amount of litter material but still provide insufficient space and height and fail to meet many of the behavioural needs of hens (Compassion in World Farming, 2007).

Hens in free-range and organic systems are kept in loose housing with elevated perches and litter material and have outdoor access, allowing them freedom of movement and the ability to express a wide repertoire of natural behaviours.

2.7 Salmon and trout

For salmon and trout, data were not available to compare organically-farmed fish with intensively-farmed fish. Studies were therefore selected that compared wild-caught fish with intensively-farmed fish.

Intensive fish farming practices often cause stress and poor welfare. Farmed fish are usually stocked at very high densities, which can have a detrimental impact on their health and welfare, especially for species that do not naturally live in close-schooling shoals. High densities can lead to increased incidence of physical injuries, stress, and susceptibility to disease; poor water quality and increased aggression (Håstein, 2004). The behaviour of farmed fish is severely restricted. Species like salmon would naturally swim great distances at sea. Confined in cages, farmed fish are unable to escape from dangers such as poor water quality or attack by predators (including other fish). Mortality rates of farmed fish are often very high compared with other farmed animals (Poppe *et al*, 2002).

There are also serious welfare concerns regarding common methods of capture, handling and processing of wild-caught fish. However, in addition to farmed fish being subjected to prolonged confinement, large numbers of wild-caught fish are subjected to inhumane capture, handling and processing in order to produce feed for farmed salmon and trout, whereas wild salmon and trout consume wild animals directly. Therefore, wild-caught fish are considered to be the higher-welfare option for the purposes of this study.

3. Key nutrients that may differ between higher- and lower-welfare production systems

The nutritional quality of animal products is influenced by many factors, including the species, breed, age and sex of the animal, the system in which the animal was reared, the composition of the animal’s diet, the geographical location, climate and season.

In addition, there may be significant differences in measurements of nutrient composition between different laboratories and with different methodology of the analyses.

Comparative data were available in the scientific literature to allow an analysis of fat content, fat composition, protein content, levels of antioxidants such as vitamin E and beta-carotene, and iron content across a range of species and products. In general, protein content and the overall proportions of saturated and unsaturated fatty acids[i] did not differ consistently between higher and lower-welfare systems, so data for these aspects are not presented. Significant differences were found in the proportions of omega-3 and omega-6 polyunsaturated fatty acids, which are relevant to human health, so the data presented for fat composition focus on these aspects. The roles of these nutrients in our diet, and the reasons why levels may differ between animal products from intensive and extensive systems, are discussed below.

[i.] The proportion of polyunsaturated fatty acids (PUFA) was often found to be higher in extensively-reared animal products and the proportion of monounsaturated fatty acids (MUFA) was often higher in intensively-reared animal products but the overall proportion of unsaturated fatty acids (PUFA and MUFA combined) generally did not differ consistently. A certain amount of specific polyunsaturated fatty acids is essential in the diet but there is no RDA set for total PUFA or total MUFA in the EU. Replacement of saturated fat in the diet with a mixture of PUFA and MUFA is considered beneficial (EFSA, 2010) but there are no clear nutritional or health benefits of consuming higher amounts of total PUFA over total MUFA or vice versa. It was therefore decided not to present data on the differences in levels of total PUFA and total MUFA between intensive and extensive animal products due to the limited relevance of the findings for human health and nutrition.

3.1 Fat quantity and composition

Fat is an important source of energy in the diet and facilitates the absorption of fat-soluble vitamins and carotenoids. However, fat is very energy dense (containing 9Kcal/g compared with 4Kcal/g for protein and carbohydrate) and excessive fat consumption can contribute to weight gain and associated health problems. High-fat diets may decrease insulin sensitivity and are positively associated with certain risk factors for cardiovascular disease (EFSA, 2010). Nutritional guidelines generally recommend total fat should be limited to no more than 30-35% of energy intake, with less than 10% of energy intake (or as little as possible within the context of a nutritionally adequate diet) coming from saturated fat (*Ibid.*).

The greater opportunity for exercise in extensive systems (and in more active breeds) may be expected to result in a reduction in the fat content of meat. Based on the studies reviewed in this report, saturated fatty acids generally make up around 20-25% of total fatty acids in salmon and trout, 30-40% in chicken and eggs, 30-50% in meat and 60-75% in milk. Given that the fat in animal products generally contains a significant proportion of saturated fat (irrespective of the production system) consumption of animal products with reduced fat content would be expected to facilitate a reduction in consumption of saturated fat as well as total fat.

In addition to the total amount of fat, the composition of the fat is important. Key differences in diet between intensive and extensive systems, in particular the consumption of fresh forage, influence the composition of fat in animal tissues, especially the levels of omega-3 fatty acids.

Essential polyunsaturated fatty acids can be divided into two groups: omega-3 and omega-6. These two groups have different and often opposing roles in the body. For example, omega-3 fatty acids have anti-inflammatory properties and omega-6 fatty acids have pro-inflammatory properties (Simopoulos, 2006).

The two groups compete for positions in cell membranes within the body and hence the composition of these membranes is dependent to a great extent on dietary intake (*Ibid.*). A number of experts have therefore highlighted the importance of achieving an appropriate balance in the amounts of each group consumed (Simopoulos, 2008; Hibbeln *et al*, 2006; Simopoulos, 2006; Cordain *et al*, 2005; Muskiet *et al*, 2004).

Modern western diets are often deficient in omega-3 fatty acids and have excessive amounts of omega-6 fatty acids relative to the amount of omega-3 (Simopolous, 2008, Hibbeln *et al*, 2006; Simopoulos, 2006; Cordain *et al*, 2005).

Anthropological and epidemiological studies indicate human beings evolved on a diet with a ratio of omega-6 to omega-3 of around 1:1, whereas in current Western diets the ratio is 15:1 to 16.7:1 (Simopoulos, 2008).

A review of the scientific evidence by Simopoulos (2008) suggests that insufficient omega-3, and an imbalance of the ratio of omega-6 to omega-3, promotes a number of serious diseases, including cardiovascular disease, cancer, osteoporosis, and inflammatory and autoimmune diseases. A ratio of omega-6 to omega-3 of 4:1 was associated with a 70% decrease in total mortality in patients with cardiovascular disease; a ratio of 2.5:1 reduced rectal cell proliferation in patients with colorectal cancer, whereas a ratio of 4:1 with the same amount of omega-3 had no effect; a lower omega-6 to omega-3 ratio in women with breast cancer was associated with decreased risk; a ratio of 2-3:1 suppressed inflammation in patients with rheumatoid arthritis, and a ratio of 5:1 had a beneficial effect on patients with asthma, whereas a ratio of 10:1 had adverse consequences.

The omega-3 fatty acids can be further sub-divided into long-chain omega-3 (those containing 20 or more carbon atoms) and shorter chain omega-3. The major long-chain omega-3 fatty acids are EPA (eicosapentaenoic acid), DPA (docosapentaenoic acid) and DHA (docosahexaenoic acid) and the major shorter-chain omega-3 is ALA (alpha-linolenic acid). ALA can be converted into the longer-chain versions in the body but the process is relatively inefficient, especially for DHA (Muskiet *et al*, 2004). It is therefore important to obtain sufficient long-chain omega-3 directly from the diet and a number of bodies have set recommended levels at around 200 to 500mg per day for EPA and DHA combined (EFSA, 2010; Harris *et al*, 2009).

Since conversion of shorter chain omega-3 to DHA within the body is believed to be limited, an additional 100 to 200mg per day of pre-formed DHA is recommended for pregnant and lactating women in order to provide sufficient DHA for the developing brain of the foetus (EFSA, 2010). Hibbeln *et al* (2006) attempted to establish healthy intakes of omega-3 and omega-6 fatty acids based on the burden of cardiovascular disease and mental illness that can be attributed to insufficient dietary intake of long-chain omega-3. They investigated dietary intakes of long-chain omega-3, the long-chain fatty acid composition of body tissues[ii] and the prevalence of morbidity and mortality from various cardiovascular and mental illnesses in 38 countries around the world. They concluded the burden of disease potentially attributable to deficiency[iii] in long-chain omega-3 is over 40% for coronary heart disease mortality, over 30% for stroke mortality, over 25% for cardiovascular disease mortality and between 65% and 99.9% for various forms of depression, although the authors suggest the figures for certain types of depression are likely to be overestimates. They recommend an intake of long-chain omega-3 equivalent to that seen in Japan would be expected to protect more than 98% of the population from increased risk of these conditions. This equates to 0.37% of energy from long-chain omega-3 or 750mg/day for EPA, DPA and DHA combined, resulting in a tissue composition of approximately 60% omega-3 in total long-chain fatty acids. However, due to varying levels of omega-6 intake, the intake of long-chain omega-3 required to achieve a comparable tissue composition ranged from less than 300mg/day in the Philippines to over 3500mg/day in the US.

3.2 Antioxidants

Antioxidants are naturally occurring compounds that can neutralise free radicals (highly reactive molecules that damage body cells). Antioxidants are thought to prevent some of the processes involved in the development of cancer (protecting DNA from oxidative damage) and cardiovascular disease (inhibiting oxidative damage to LDL (low density lipoprotein or "bad") cholesterol) (Schönfeldt and Holden, 2009).

Vitamin E acts as an antioxidant in cell membranes and plasma lipoproteins (complex aggregates of lipid (fat) molecules and protein molecules) and is especially important in limiting damage from free-radicals generated during the oxidation of polyunsaturated fatty acids. There is epidemiological evidence that high intakes of vitamin E are associated with lower incidence of cardiovascular disease (Bender, 2009). Alpha-tocopherol is the most biologically active form of vitamin E. The adult recommended daily allowance (RDA) for vitamin E in the EU is 12mg (Council Directive 90/496/EEC).

Carotenoids, such as beta-carotene and lutein, also act as antioxidants. There is epidemiological evidence that diets rich in carotenoids are associated with a lower incidence of cancer and cardiovascular disease, although intervention studies using beta-carotene supplements have not demonstrated this (Bender, 2009) and it is therefore recommended that beta-carotene be obtained from food rather than from supplements (Taylor Mayne, 1996). In addition to their role as antioxidants, certain carotenoids can be converted into vitamin A in the body (provitamin A carotenoids).

There is no specific RDA set for any of the carotenoids in terms of their antioxidant function. The adult RDA for vitamin A in the EU is 800µg (Council Directive 90/496/EEC). 12µg of beta-carotene is equivalent to 1µg of retinol (pre-formed vitamin A) (Bender, 2009). In terms of its role as a precursor of vitamin A therefore, 9600µg of beta-carotene would be equivalent to the RDA for vitamin A. Lutein is a non-provitamin A carotenoid and therefore there is no RDA for lutein.

Fresh forage generally contains higher levels of antioxidants than conserved forage and concentrate feeds, which may be expected to translate into higher levels of antioxidants in the meat, milk and eggs produced from animals grazing pasture compared with those confined indoors.

[ii] Estimated based on dietary intakes of LA, ALA, AA and EPA+DPA+DHA.

[iii] Defined as "an increased risk of chronic diseases for which substantial efficacy data exist and for which these nutrients reduce pathophysiologic mechanisms".

3.3 Iron

Iron facilitates many metabolic functions, including the transport of oxygen in the blood (via haemoglobin) and the storage of oxygen in muscles (via myoglobin). Iron is also a component of various enzymes that are critical for the production of energy from food and for immune system functioning (Strain and Cashman, 2009). Iron deficiency causes anaemia, which is associated with fatigue, restlessness and impaired work performance and can adversely affect psychomotor and mental development of children (*Ibid.*). The adult RDA for iron in the EU is 14mg (Council Directive 90/496/EEC).

The greater physical activity of animals reared in extensive systems would be expected to lead to an increase in myoglobin in the muscles, and therefore to an increase in the iron content of the muscles which are eaten as meat. The breed of animal may also be expected to affect iron levels. Breeds of animal that have been selected for increased growth rate and altered body conformation, such as fast-growing meat chickens, are relatively inactive, which would be expected to reduce the myoglobin (and hence the iron) content of the meat.

4. Analysis of nutritional differences between higher- and lower-welfare animal products

A literature review was conducted to identify studies comparing the nutritional composition of animal products from intensive and extensive systems. For most species, studies were included that were published since 2000. However, fewer studies were available for eggs and fish so studies published since 1990 were included for these.

Studies with very small sample sizes and studies not published in English were excluded. Studies (or data within a study) were also excluded where animals in one or other of the systems to be compared were supplemented with additional quantities of any of the nutrients of interest, either through direct supplementation with the nutrient (above levels normally added to conventional feedstuffs) or through the use of feedstuffs specifically selected for their high levels of the nutrient (e.g. fishmeal or linseed for omega-3 fatty acids). Some studies also examined other aspects of food quality or safety but these aspects are beyond the remit of this analysis and are not examined here.

In some cases, mean values were used from multiple sets of data presented in a study. This may apply, for example, where studies present data for several muscle types or from several production systems that are equivalent from an animal-welfare perspective (e.g. multiple grazing systems with different species composition of the pasture). For chicken, data for different muscle types were not pooled because of the major differences in composition between breast meat and leg/thigh meat. Where a range of slaughter ages and/or weights were compared in a study, the data used here were those considered most representative of commercial practice.

4.1 Lamb

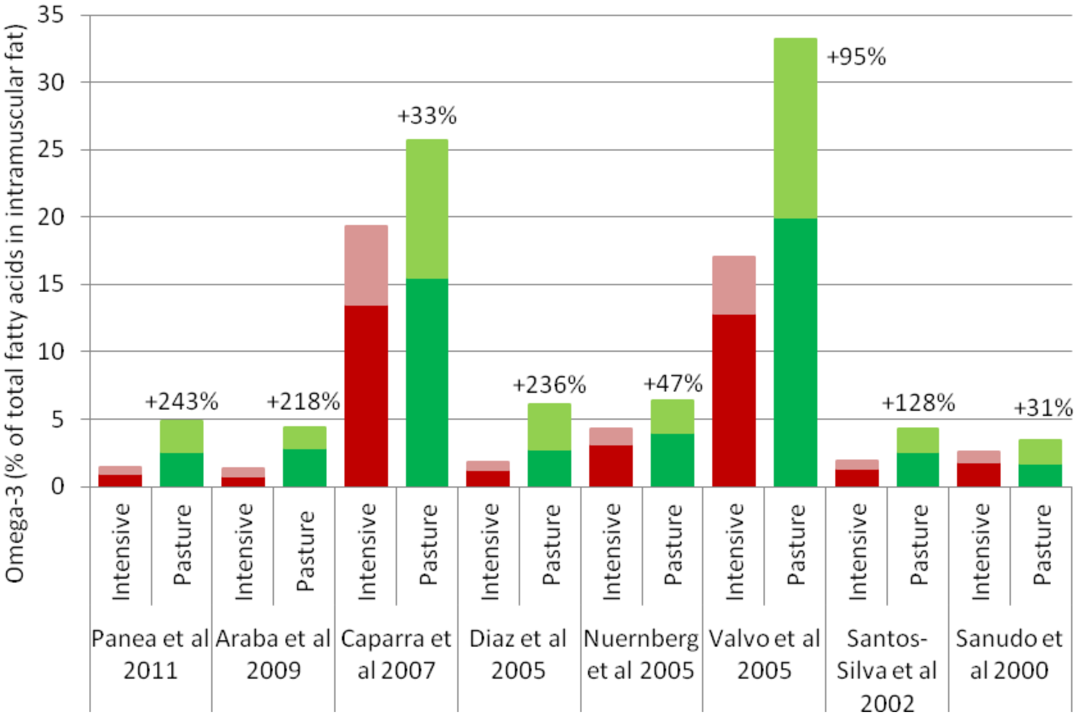
The total amount of intramuscular fat (i.e. fat content of lean meat trimmed of visible fat) is generally similar in lamb from intensive and pasture-based systems, with most studies that measured this reporting no significant difference (Panea *et al*, 2011; Valvo *et al*, 2005; Santos Silva *et al*, 2002).

However, the composition of the fat is markedly different between intensive and pasture-reared lamb. The proportion of omega-3 fatty acids is between one third and five times higher in pasture-reared lamb (Fig. 1). The ratio of omega-6 to omega-3 fatty acids is between 20% and 84% lower in pasture-reared lamb compared with intensively-reared lamb (Panea *et al*, 2011; Kitessa *et al*, 2010; Araba *et al*, 2009; Nuernberg *et al*, 2008; Caparra *et al*, 2007; Diaz *et al*, 2005; Nuernberg *et al*, 2005; Valvo *et al*, 2005; Santos-Silva *et al*, 2002; Sanudo *et al*, 2000). All the pasture-reared lamb has a healthy low omega-6/omega-3 ratio of between 0.6 and 3.1. The ratio is more variable for intensively-reared lamb, ranging from 1.3 to 8.4.

A number of studies report the amount of omega-3 per 100g of lean meat, ranging from 31 to 78mg in intensively-reared lamb and from 65 to 130mg in pasture-reared lamb (Kitessa *et al*, 2010; Nuernberg *et al*, 2008; Diaz *et al*, 2005; Nuernberg *et al*, 2005; Sanudo *et al*, 2000). In some cases, levels may be much higher, with omega-3 representing over a quarter (Caparra *et al*, 2007) or as much as one third (Valvo *et al*, 2005) of total fatty acids in pasture-reared lamb (Fig. 1). The latter is equivalent to around 400mg of omega-3 per 100g of lean meat (including 240mg long-chain omega-3, of which 68mg is DHA).[iv.] Typically around half or more of the omega-3 in lamb is made up of long-chain (≥20 carbons) omega-3 (Fig. 1).

These amounts are significant in terms of human nutritional requirements (see Section 3.1) and indicate pasture-reared lamb can make a significant contribution to meeting nutritional requirements for long-chain omega-3. This is supported by data from Australia, where consumption of beef and lamb from predominantly grass-fed animals is estimated to contribute 28% of total dietary intake of long-chain omega-3 (Howe *et al*, 2006).

Figure 1. Omega-3 content and percentage difference between lamb from intensive and pasture-based systems. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. Bars represent the total omega-3 fatty acids measured in each study, which may not necessarily include all omega-3 fatty acids present in the samples. Studies are included if they present data for at least one of the major long-chain omega-3 fatty acids (EPA, DPA and/or DHA) and the major shorter-chain omega-3 fatty acid (ALA).



A short-term (4-week) study by McAfee *et al* (2011) found a measurable effect of consumption of grass-fed beef and lamb on levels of omega-3 in human blood. Volunteers consumed around 470g per week of either grass-fed beef and lamb or beef and lamb from animals finished intensively on a concentrate-based diet. After four weeks, mean levels of long-chain omega-3 in blood plasma and platelets were increased in those people consuming the grass-fed products and decreased in those people consuming the concentrate-fed products. At the end of the trial, the proportion of long-chain omega-3 was 62% higher in the plasma and 23% higher in the platelets of those people who consumed grass-fed products compared with those who consumed concentrate-fed products. Both these differences were highly statistically significant ($P<0.01$ and $P<0.001$ respectively). These data indicate that consuming moderate amounts of beef and lamb from animals reared at pasture rather than animals reared intensively can rapidly have a beneficial effect on levels of long-chain omega-3 fatty acids.

No data were available to compare levels of antioxidants or iron between intensively-reared and pasture-reared lamb.

[iv.] Based on total intramuscular fat of 1.31 g/100g reported by Valvo *et al* (2005) and a conversion factor of 0.916 to give total fatty acids in fat in lean lamb (from MAFF, 1998).

SUMMARY OF FINDINGS FOR LAMB

- There are no consistent differences in total intramuscular fat content between lamb from pasture-based and intensive systems;
- Pasture-reared lamb has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with intensively-reared lamb;
- Pasture-reared lamb can make a significant contribution to meeting nutritional requirements for long-chain omega-3 fatty acids and in some cases contains appreciable amounts of DHA;
- An increase in long-chain omega-3 fatty acids in blood plasma and platelets has been demonstrated in human trials following consumption of pasture-reared beef and lamb as opposed to intensively-reared beef and lamb.

4.2 Beef

The total amount of intramuscular fat is between 25% and 47% lower in pasture-reared beef compared with intensively-reared beef (Fig. 2). Under EU legislation (Regulation (EC) No. 1924/2006) food products can be labelled as “low in fat” if they contain less than 3g of fat per 100g. In all of the studies, pasture-reared beef trimmed of visible fat would qualify as a low-fat product, compared with only two out of eight studies for intensively-reared beef.

There are significant differences in fat composition between intensively-reared and pasture-reared beef. The proportion of omega-3 fatty acids is generally between two and five times higher in pasture-reared beef (except for one study where the difference was not statistically significant) (Fig. 3).

Also, the ratio of omega-6 to omega-3 fatty acids is between 35% and 85% lower in pasture-reared beef compared with intensively-reared beef (Alfaia *et al*, 2009; Garcia *et al*, 2008; Latimori *et al*, 2008; Leheska *et al*, 2008; Ponnampalam *et al*, 2006; Descalzo *et al*, 2005; Realini *et al*, 2004; Varela *et al*, 2004). All the pasture-reared beef has a healthy low omega-6 to omega-3 ratio of between 1.4 and 3.7. The ratio is more variable for intensively-reared beef, ranging from 2.8 to 14.2.

Two studies report the amount of omega-3 per 100g of lean meat: Garcia *et al* (2008) found levels of 32mg in intensively-reared beef and 84mg in pasture-reared beef; Ponnampalam *et al* (2006) found levels of 76mg in intensively-reared beef and 129mg in pasture-reared beef. These levels are generally comparable with the levels found in lamb (see Section 4.1).

Figure 2. Intramuscular fat content and percentage difference between beef from intensive and pasture-based systems.

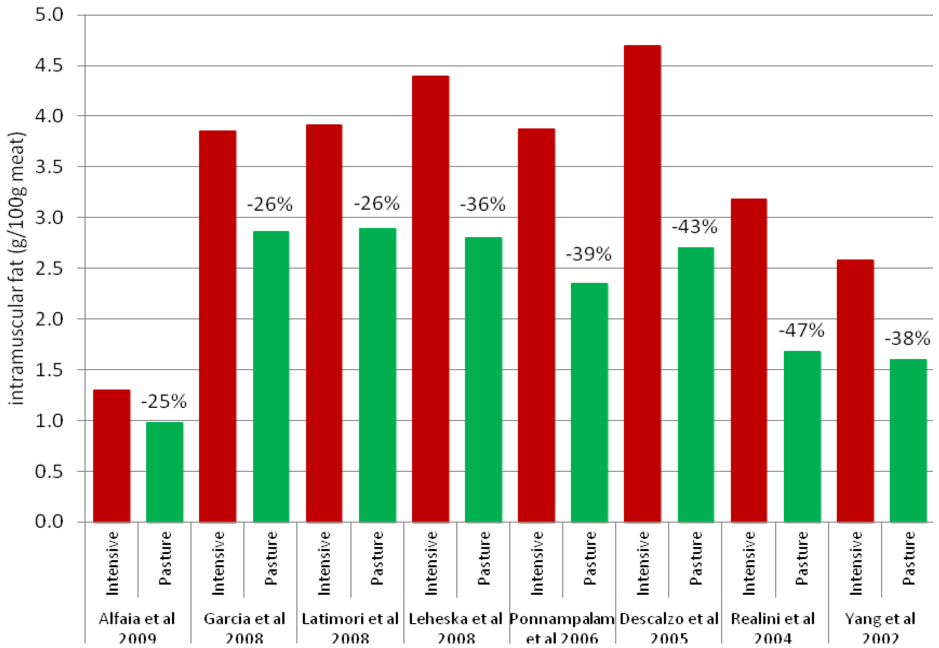
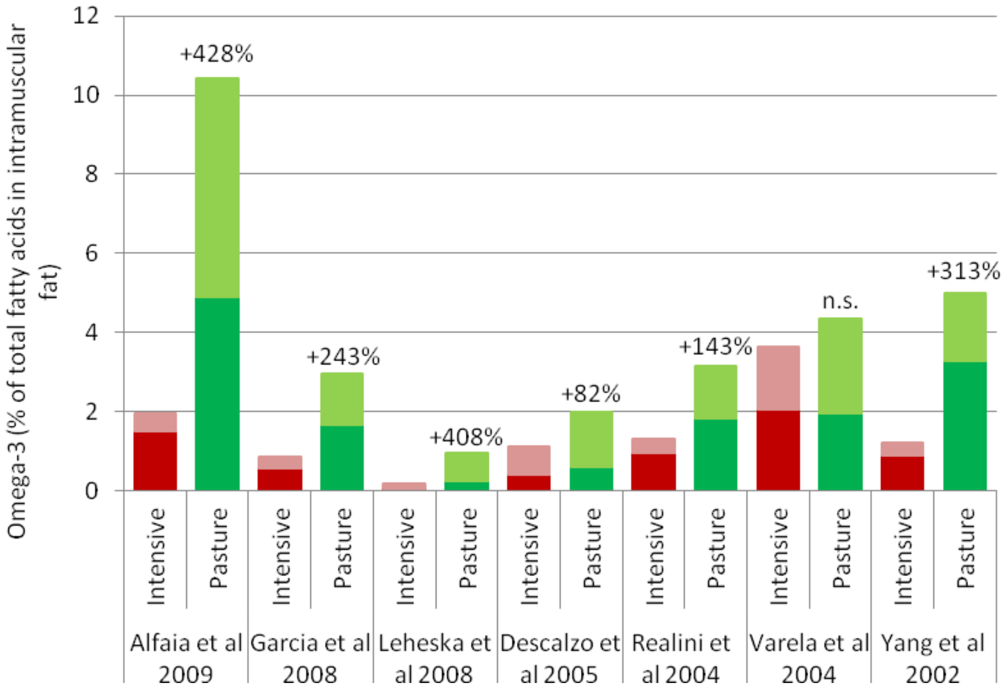


Figure 3. Omega-3 content and percentage difference between beef from intensive and pasture-based systems. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. n.s. = difference not statistically significant. Bars represent the total omega-3 fatty acids measured in each study, which may not necessarily include all omega-3 fatty acids present in the samples. Studies are included if they present data for at least one of the major long-chain omega-3 fatty acids (EPA, DPA and/or DHA) and the major shorter-chain omega-3 fatty acid (ALA).



However, compared with lamb, a higher proportion of the omega-3 in beef is made up of ALA, with typically less than half being long-chain omega-3 (Fig. 3). Nonetheless, both pasture-reared lamb and pasture-reared beef can make a significant contribution to meeting human nutritional requirements for long-chain omega-3 (see Section 3.1 and Section 4.1).

Based on the findings of Garcia *et al* (2008) and Ponnampalam *et al* (2006), a person would have to consume between 1.7 and 2.6 times the quantity of intensively-reared beef, and thus between 2.8 and 3.5 times the quantity of fat (Table 1), in order to obtain the same amount of omega-3 found in a 100g serving of pasture-reared beef. In light of nutritional advice to limit intake of fat, especially saturated fat (see Section 3.1) and to restrict consumption of red meat to no more than 500g per week (World Cancer Research Fund, 2011), the potential contribution of intensively-reared beef to meeting long-chain omega-3 requirements is greatly limited compared with the potential contribution of pasture-reared beef, within the confines of a healthy balanced diet.

In addition to being lower in fat and having a more favourable fatty acid composition, pasture-reared beef also contains higher levels of antioxidants. Levels of vitamin E are between 34% and 161% higher in pasture-reared beef compared with intensively-reared beef (Fig. 4). A 100g serving of beef from a pasture-based system provides between 0.2mg and 0.5mg of vitamin E, which is equivalent to between 1.7% and 4.2% of the RDA (see Section 2.2). A 100g serving of intensively-reared beef provides between 0.08mg and 0.3mg of vitamin E, which is equivalent to between 0.7% and 2.5% of the RDA.

Levels of beta-carotene are between 335% and 700% higher for pasture-reared beef (Fig. 5). Levels range from 16µg to 74µg per 100g of meat for beef from pasture-based systems and from 2 to 17µg/100g for intensively-reared beef. These amounts are relatively low in terms of the role of beta-carotene as a precursor of vitamin A, equivalent to less than 1% of the RDA for vitamin A. No data were available to compare levels of iron between intensively-reared and pasture-reared beef.

Table 1: Comparison of intramuscular fat and omega-3 levels in beef from intensive and pasture-based systems. Within studies, statistically significant differences are indicated by different superscript letters (lower case = $P<0.05$; upper case = $P<0.001$).

REFERENCE	**Garcia *et al* 2008**		**Ponnampalam *et al* 2006**	
Production system	**PASTURE**	**INTENSIVE**	**PASTURE**	**INTENSIVE**
Intramuscular fat (g/100g lean meat)	2.86^{a}	3.85^{b}	2.35^{A}	3.87^{B}
Omega-3 (mg/100g lean meat)	84^{A}	32^{B}	129^{A}	76^{B}
Product consumed to obtain the same amount of omega-3 as in 100g of pasture-reared product (g)		263		170
Fat consumed to obtain the same amount of omega-3 as in 100g of pasture-reared product (g)		10.1		6.6

SUMMARY OF FINDINGS FOR BEEF

- Pasture-reared beef contains less intramuscular fat than intensively-reared beef;
- Pasture-reared beef has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with intensively-reared beef;
- Pasture-reared beef can make a significant contribution to meeting nutritional requirements for long-chain omega-3 fatty acids;
- An increase in long-chain omega-3 fatty acids in blood plasma and platelets has been demonstrated in human trials following consumption of pasture-reared beef and lamb as opposed to intensively-reared beef and lamb;
- Pasture-reared beef contains more vitamin E than intensively-reared beef, with up to 4% of the adult RDA in a 100g serving;
- Pasture-reared beef contains more beta-carotene than intensively-reared beef, although the amounts are relatively small (equivalent to less than 1% of the adult RDA for vitamin A in a 100g serving).

Figure 4. Vitamin E content and percentage difference between beef from intensive and pasture-based systems.

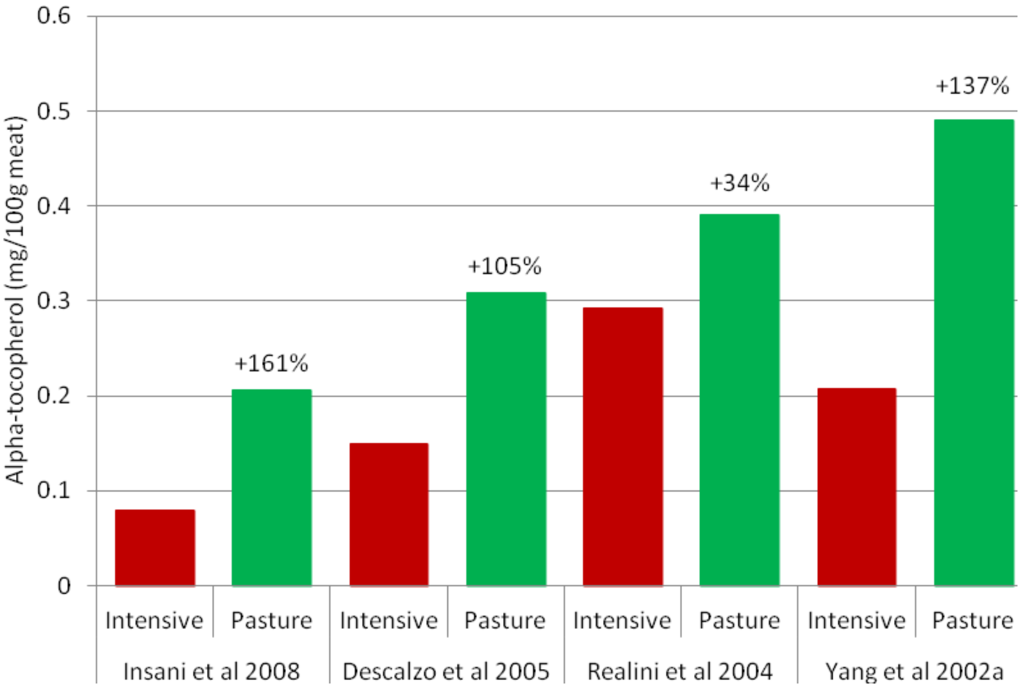
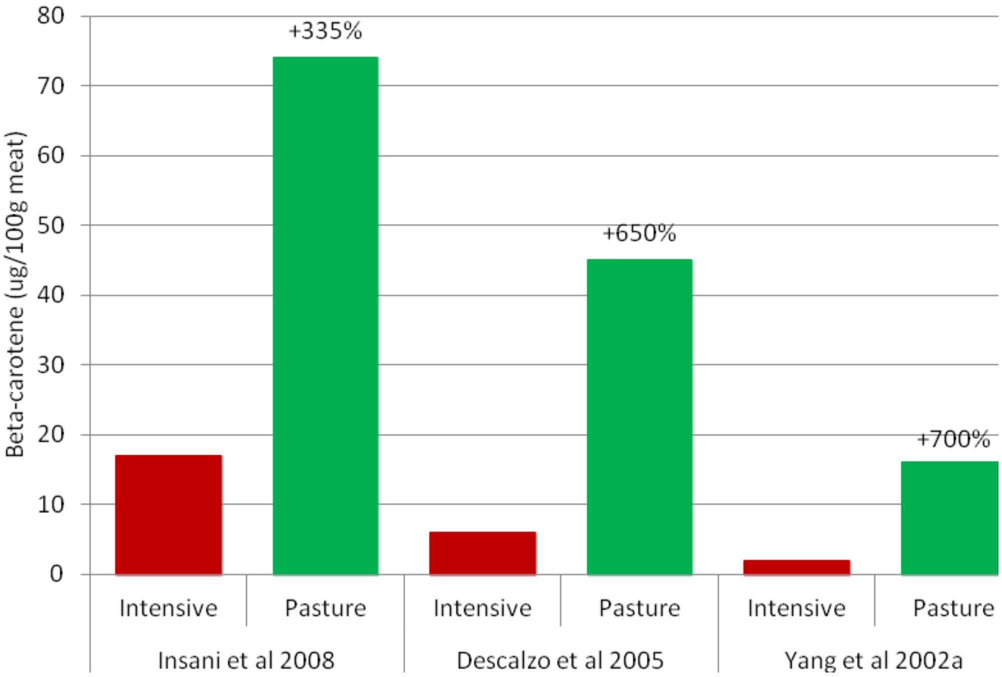


Figure 5. Beta-carotene content and percentage difference between beef from intensive and pasture-based systems.



4.3 Milk

Milk fat content ranges from 3.2% to 4.6% in the studies reviewed. There are no consistent differences in the total amount of fat between milk from intensive and pasture-based systems. Some studies report higher levels of fat in milk from intensive systems (Couvreur *et al*, 2006; Schroeder *et al*, 2005; White *et al*, 2001) whilst other studies report higher levels in milk from organic and other pasture-based systems (Butler *et al*, 2011; Slots *et al*, 2009; Kay *et al*, 2005; Leiber *et al*, 2005). In either case, the total amount of fat may be less relevant from a nutritional perspective for milk as consumers often choose milk or milk products with part (semi-skimmed) or most (skimmed) of the fat removed. Milk fat is considered useful however in the processing of milk into products such as cheese, butter and cream. The composition of the fat may therefore be more important than the actual amount, since these products generally have a high fat content regardless of the original fat content of the milk.

There are significant differences in fat composition between milk from intensive and pasture-based systems. The proportion of omega-3 fatty acids is between 50% and 184% higher in milk from pasture-based systems (Fig. 6). Also, the ratio of omega-6 to omega-3 fatty acids is between 30% and 79% lower in milk from pasture-based systems compared with milk from intensive systems (Butler *et al*, 2011; Bilik *et al*, 2010; Slots *et al*, 2009; Ellis *et al*, 2006; Leiber *et al*, 2005). All the milk from pasture-based systems has a healthy low omega-6 to omega-3 ratio of between 1.0 and 3.5. Although generally higher, the omega-6 to omega-3 ratio for milk from intensive systems is also relatively low, at between 2.5 and 5.1.

Based on typical omega-3 proportions in milk fat of 0.5% in milk from intensive systems and 1% in milk from pasture-based systems, and a typical milk fat content of 4%, amounts of omega-3 would be expected to be in the region of 19mg and 38mg per 100ml of milk from intensive and pasture-based systems, respectively.[v.] Most of this is made up of ALA, with typically 20% or less being long-chain omega-3 (Fig. 6). These amounts are relatively small in terms of human nutritional requirements (see Section 2.1). However, although milk may not be an especially rich source of omega-3 by itself, within the context of a diet where most or all animal products are sourced from extensive systems, consumption of milk from pasture-based systems rather than intensive systems would be expected to further contribute to meeting requirements for omega-3 intake and achieving a healthy balance of omega-6 to omega-3.

[v.] Based on a conversion factor of 0.945 to give total fatty acids in milk fat (from MAFF, 1998).

Figure 6. Omega-3 content and percentage difference between milk from intensive and pasture-based systems. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. Bars represent the total omega-3 fatty acids measured in each study, which may not necessarily include all omega-3 fatty acids present in the samples. Studies are included if they present data for at least one of the major long-chain omega-3 fatty acids (EPA, DPA and/or DHA) and the major shorter-chain omega-3 fatty acid (ALA). * Data from La Terra *et al* (2010) are % of lipids rather than % of fatty acids.

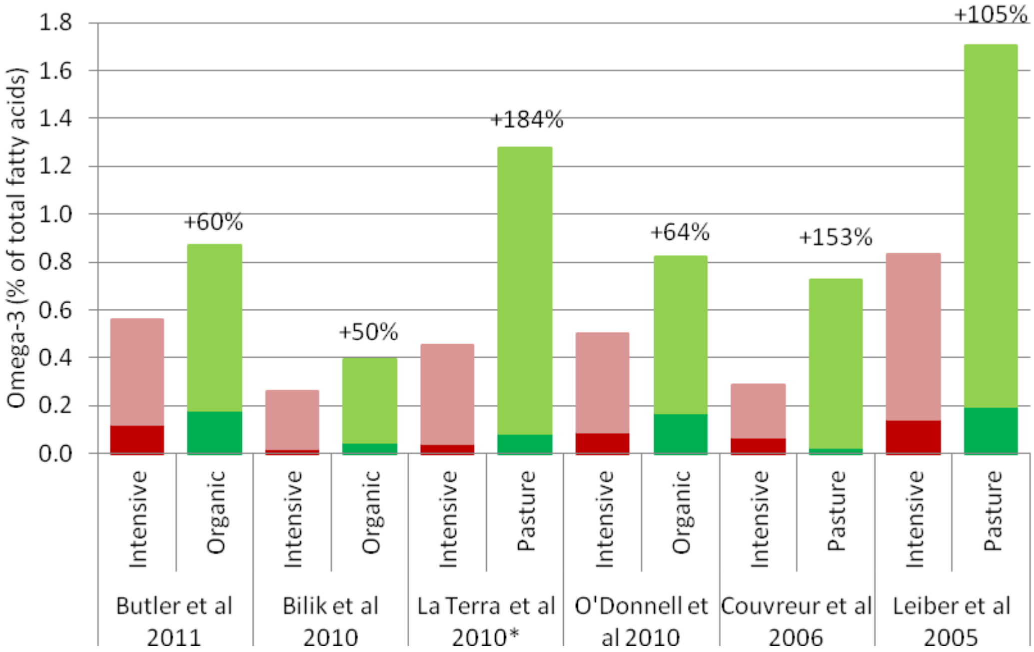


Figure 7. Vitamin E content and percentage difference between milk from intensive and pasture-based systems.
n.s. = difference not statistically significant.

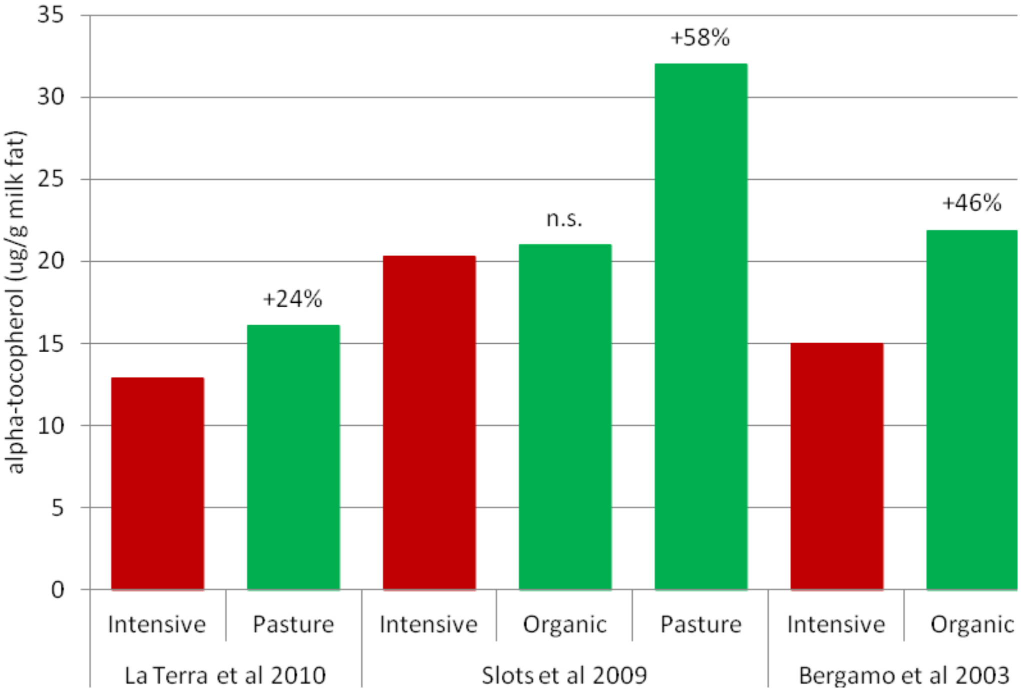
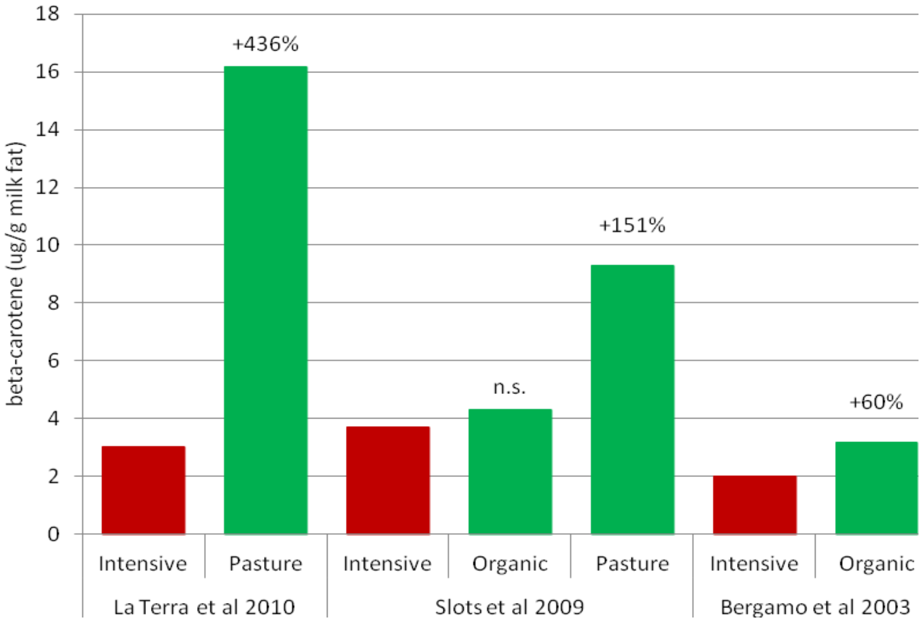


Figure 8. Beta-carotene content and percentage difference between milk from intensive and pasture-based systems.
n.s. = difference not statistically significant.



Milk from pasture-based systems contains higher levels of antioxidants. Levels of vitamin E are generally between 24% and 58% higher in milk from pasture-based systems compared with intensive systems (except for one comparison where the difference was not significant) (Fig. 7). However, the levels are relatively low in terms of human nutritional requirements. Based on a typical milk fat content of 4%, a 100ml serving of milk from a pasture-based system provides between 0.06mg and 0.13mg of vitamin E, which is equivalent to between 0.5% and 1% of the RDA (see Section 3.2). A 100ml serving of milk from an intensive system provides between 0.05mg and 0.08mg of vitamin E, which is equivalent to between 0.4% and 0.7% of the RDA.

Levels of beta-carotene are generally between 60% and 436% higher for milk from pasture-based systems (except for one comparison where the difference was not significant) (Fig. 8). However, the levels are relatively low in terms of human nutritional requirements. Based on a typical milk fat content of 4%, a 100ml serving of milk from a pasture-based system provides between 64µg and 128µg of beta-carotene, which is equivalent to between 0.7% and 1.3% of the RDA for vitamin A (see Section 3.2). A 100ml serving of milk from an intensive system provides between 52µg and 81µg of beta-carotene, which is equivalent to between 0.5% and 0.8% of the RDA for vitamin A.

No data were available to compare levels of iron between milk from intensive and pasture-based systems.

SUMMARY OF FINDINGS FOR MILK

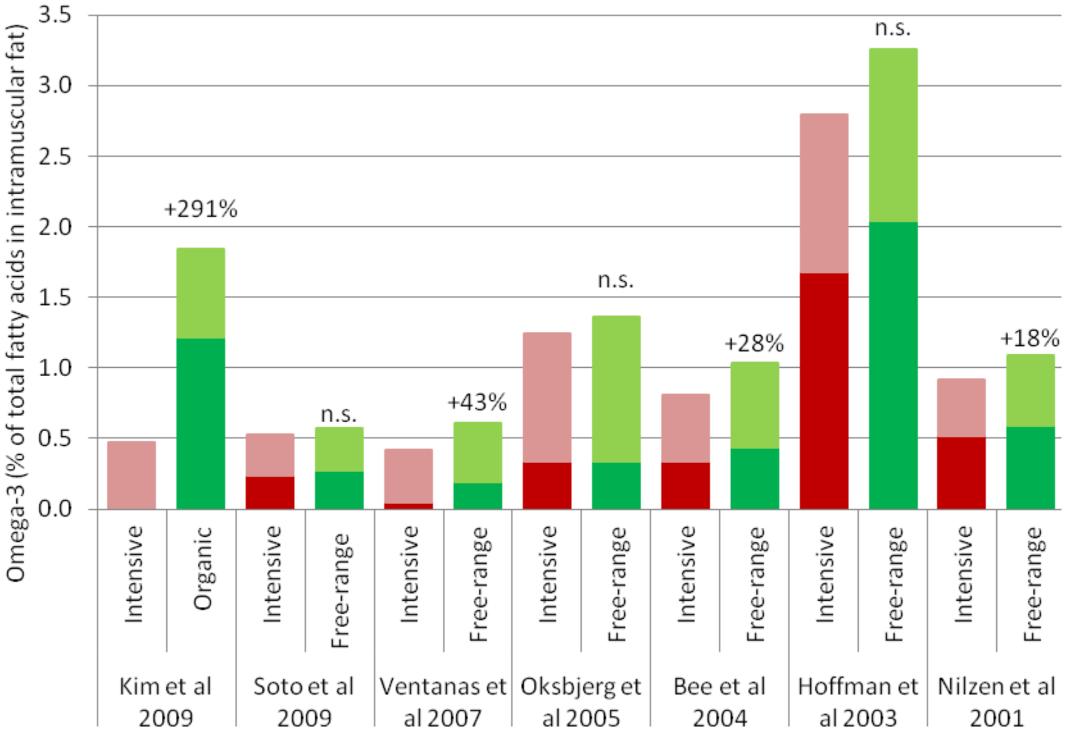
- There are no consistent differences in total fat content between milk from pasture-based systems and intensive systems;
- Milk from pasture-based systems has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with milk from intensive systems, although the amounts would be expected to make only a relatively minor contribution to dietary intake of omega-3 and the omega-6 to omega-3 ratio is relatively low in all systems;
- Milk from pasture-based systems contains more vitamin E than milk from intensive systems, although the amounts are relatively small (less than 1% of the adult RDA in a 100ml serving);
- Milk from pasture-based systems contains more beta-carotene than milk from intensive systems, although the amounts are relatively small (equivalent to less than 1.5% of the adult RDA for vitamin A in a 100ml serving).

4.4 Pig meat

The total amount of intramuscular fat is highly variable, ranging from 1.2g to 9.0g per 100g of lean meat, and there are no consistent differences in total fat content between pig meat from intensive and extensive systems. Some studies report higher levels of fat in intensively-reared pig meat (Trombetta *et al*, 2009; Hansen *et al*, 2006) whilst other studies report higher levels in free-range pig meat (Butko *et al*, 2007; Carrapiso *et al*, 2007; Ventanas *et al*, 2007) and others report no significant difference (Kim *et al*, 2009; Gonzalez & Tejeda, 2007; Bee *et al*, 2004; Hoffman *et al*, 2003; Nilzen *et al*, 2001). Two of the three studies showing a higher fat content in free-range pig meat are traditional Spanish outdoor systems for the production of Iberian ham (Carrapiso *et al*, 2007; Ventanas *et al*, 2007), where the higher fat content of the meat can be explained by the large quantities of acorns in the diet of the free-range pigs. These are naturally high in monounsaturated fat and contribute to achieving the desired sensory characteristics of the finest commercial grade of Iberian ham.

There are significant differences in the composition of the fat between indoor and extensive systems. The proportion of omega-3 fatty acids is higher in free-range pig meat, although the difference is not statistically significant in three studies. Where significant differences are found, the proportion of omega-3 is between 18% and 43% higher for free-range pig meat and 291% higher for organic pig meat than that from intensive systems (Fig. 9).

Figure 9. Omega-3 content and percentage difference between pig meat from intensive and free-range/organic systems. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. n.s. = difference not statistically significant. Bars represent the total omega-3 fatty acids measured in each study, which may not necessarily include all omega-3 fatty acids present in the samples. Studies are included if they present data for at least one of the major long-chain omega-3 fatty acids (EPA, DPA and/or DHA) and the major shorter-chain omega-3 fatty acid (ALA).

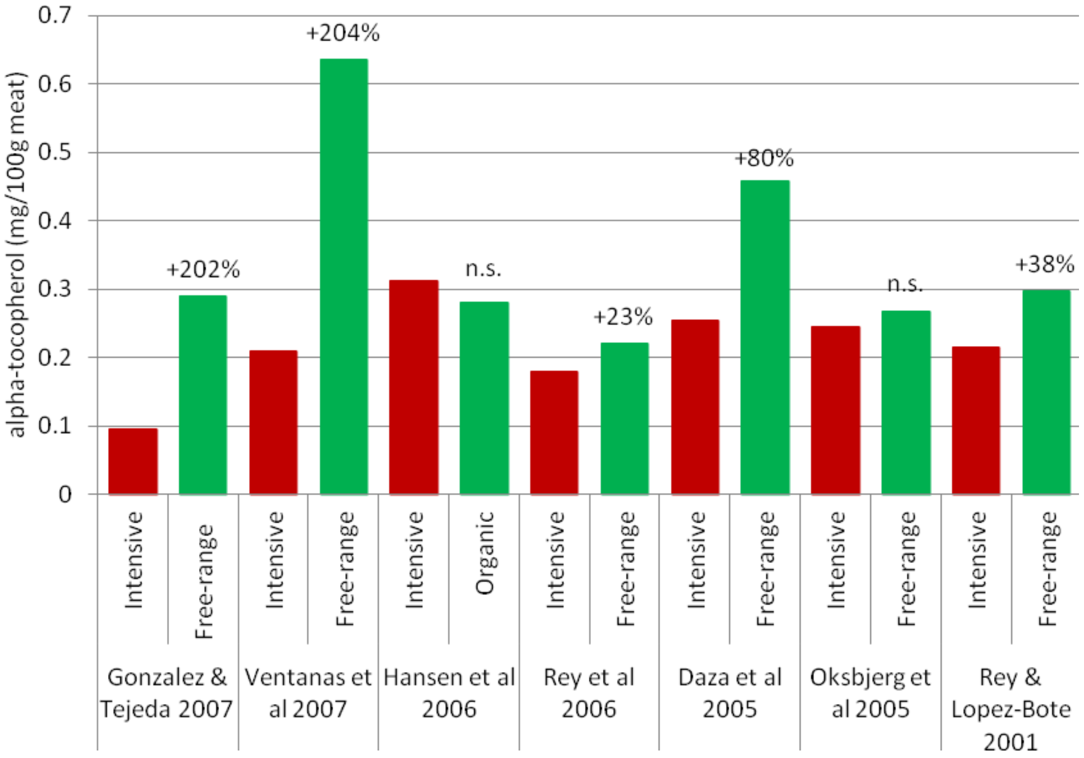


The majority of studies report a lower ratio of omega-6 to omega-3 fatty acids for free-range pig meat, ranging from a 7% to 42% reduction compared with intensively-reared pig meat (Soto *et al*, 2009; Ventanas *et al*, 2007; Bee *et al*, 2004). Two studies report no significant difference (Oksbjerg *et al*, 2005; Nilzen *et al*, 2001). Kim *et al* (2009) report a 53% lower omega-6 to omega-3 ratio for organic pig meat compared with intensively-reared pig meat. However, the omega-6 to omega-3 ratio is relatively high for pig meat from all systems, ranging from 11.8 to 18.1 for extensive systems and from 12.4 to 31.2 for intensive systems.

Based on typical omega-3 proportions of 1% of fatty acids in intramuscular fat in intensively-reared pig meat and 1.4% in pig meat from extensive systems, and a typical fat content of 4%, omega-3 levels would be expected to be in the region of 36mg and 51mg per 100g of lean pig meat from intensive and extensive systems, respectively.[vi.] The proportion of omega-3 in pig meat that is made up of long-chain omega-3 varies widely but is commonly between 30% and 60% (Fig. 9). The generally lower amounts of omega-3 and higher omega-6 to omega-3 ratio mean that the potential contribution of pig meat to meeting human nutritional requirements for long-chain omega-3 is likely to be relatively minor compared with lamb and beef. This is supported by data from Australia indicating that pork contributes around 4% of long-chain omega-3 intake (Howe *et al*, 2006). Nonetheless, the composition of free-range and organic pig meat can be considered more favourable than that of intensively-produced pig meat in this respect.

Levels of vitamin E are generally between 23% and 204% higher in pig meat from extensive systems compared with intensive systems (except for two comparisons that show no significant difference) (Fig. 10). A 100g serving of free-range or organic pig meat provides between 0.2mg and 0.6mg of vitamin E, which is equivalent to between 1.7% and 5% of the RDA (see Section 3.2). A 100g serving of intensively-reared pig meat provides between 0.1mg and 0.3mg of vitamin E, which is equivalent to between 0.8% and 2.5% of the RDA.

Figure 10. Vitamin E content and percentage difference between pig meat from intensive and free-range/organic systems.
n.s. = difference not statistically significant.



Hoffman *et al* (2003) report iron levels 213% higher in free-range pig meat compared with intensively-produced pig meat: 0.5mg and 0.16mg per 100g of lean meat respectively. This is equivalent to 3.6% of the RDA for a 100g serving of free-range pig meat compared with 1.1% of the RDA for a 100g serving of intensively-reared pig meat (see Section 3.3).

[vi.] Based on a conversion factor of 0.910 to give total fatty acids in fat in lean pork (from MAFF, 1998).

SUMMARY OF FINDINGS FOR PIG MEAT

- There are no consistent differences in total intramuscular fat content between pig meat from free-range/organic systems and intensive systems;
- Pig meat from free-range and organic systems has a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids compared with pig meat from intensive systems, although the amounts would be expected to make only a relatively minor contribution to dietary intake of omega-3 and the omega-6 to omega-3 ratio is relatively high in all systems;
- Free-range pig meat contains more vitamin E than intensively-reared pig meat, with up to 5% of the adult RDA in a 100g serving;
- Free-range pig meat contains more iron than intensively-reared pig meat, with up to 3.5% of the adult RDA in a 100g serving.

4.5 Chicken meat

Total intramuscular fat content is generally between 8% and 49% lower for chicken meat from free-range and organic systems compared with indoor systems (two studies found no significant difference) (Fig. 11). Fat content of chicken meat is also lower for slower-growing genotypes compared with conventional fast-growing genotypes (Fig. 12). Medium-growing strains generally contain between 12% and 31% less fat than fast-growing strains (one study showed no significant difference). Slow-growing strains generally contain between 17% and 67% less fat than fast-growing strains.

Figure 11. Intramuscular fat content and percentage difference between chicken meat from various indoor and outdoor production systems.
n.s. = difference not statistically significant. Chicken genotype indicated in parentheses as follows: F = fast-growing; M = medium-growing; S = slow-growing.

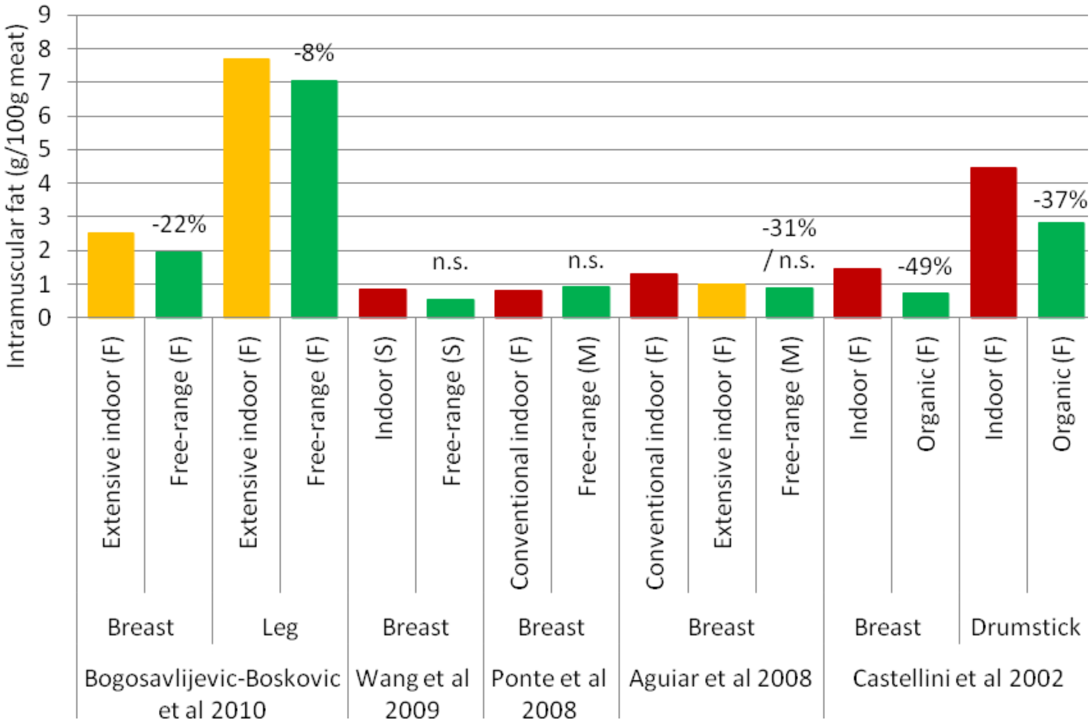
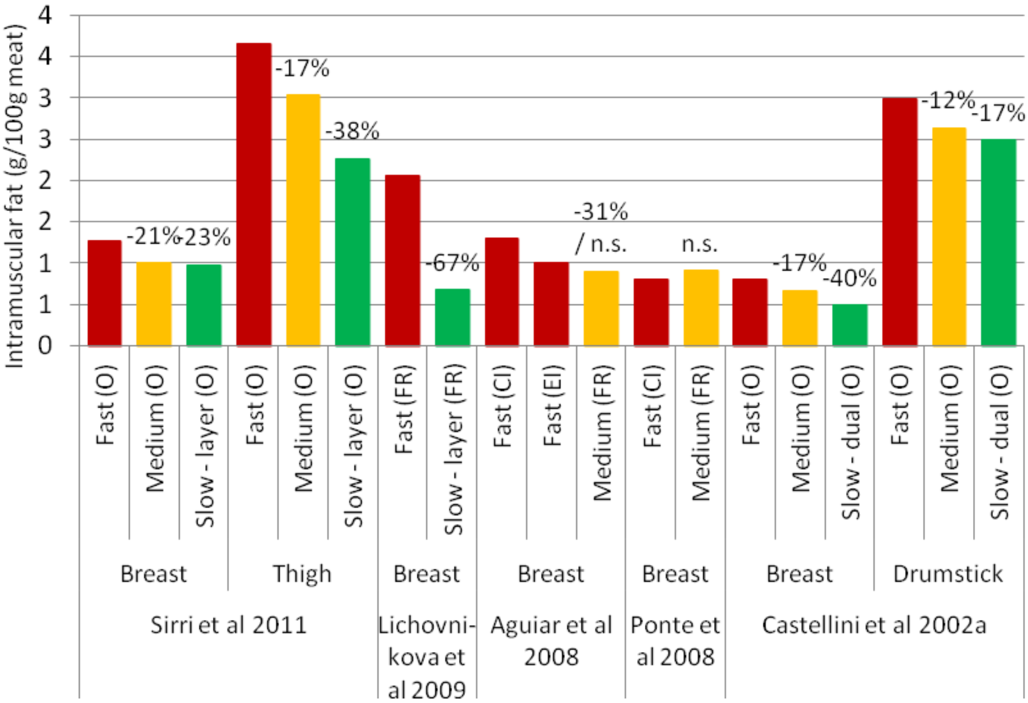


Figure 12. Intramuscular fat content and percentage difference between meat from fast-, medium- and slow-growing chicken genotypes.

n.s. = difference not statistically significant. Production system indicated in parentheses as follows: I = indoor; CI = conventional indoor; EI = extensive indoor; FR = free-range; O = organic.



The proportion of omega-3 fatty acids tends to be higher in chicken meat from free-range systems compared with indoor systems but the differences are not consistent across all studies. Several studies report a greater proportion of omega-3 fatty acids in free-range systems but others report no significant difference and one study found a lower proportion (Fig. 13). Castellini *et al* (2002) found significant differences between chicken meat from organic and indoor systems. On average, the proportion of omega-3 was 24% higher in the breast meat of organic birds (5.3% vs 4.3%) and 48% higher in the drumstick of organic birds (4.8% vs 3.2%) compared with intensively-reared birds.[vii.]

The proportion of omega-3 fatty acids also tends to be higher in medium-growing strains compared with fast-growing strains but again the differences are not consistent across all studies. Several studies report a greater proportion of omega-3 fatty acids in medium-growing strains but others report no significant difference and one study found a lower proportion (Fig. 14). Castellini *et al* (2002) found no significant difference in the proportion of omega-3 between a fast-growing strain, a medium-growing strain and a slow-growing dual-purpose strain.[vii.]

However, the differences appear to be much greater for very slow-growing layer-type strains. Sirri *et al* (2011) found that a layer strain contained double the proportion of omega-3 in the breast meat and 48% more in the thigh meat compared with a fast-growing strain (Fig. 14). Despite having 23% less fat, the breast meat of the layer strain contains over twice as much long-chain omega-3 as that of the fast-growing strain. The breast meat of the layer-type bird has 75mg omega-3 per 100g, of which 67mg is long-chain omega-3 (including 23mg of DHA). This compares with 49mg/100g, including 31mg long-chain (with 8mg DHA), for the fast-growing strain.[viii.] Meat chickens have been selected for both faster growth rate and higher meat yield, particularly breast meat yield. These findings suggest that breeding meat chickens for one or both of these traits (even to a moderate extent as in dual-purpose birds) may have had a serious detrimental impact on the nutritional quality of the meat. This is likely to be, at least in part, a result of the relative inactivity of the birds selected for meat traits compared with layer-type birds.

[vii.] Data not presented in Fig. 13 because figures for shorter-chain omega-3 were not reported.

[viii.] Based on a conversion factor of 0.945 to give total fatty acids in fat in poultry (from MAFF, 1998).

Figure 13. Omega-3 content and percentage difference between chicken meat from various indoor and outdoor production systems. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. n.s. = difference not statistically significant. Chicken genotype indicated in parentheses as follows: F = fast-growing; M = medium-growing.

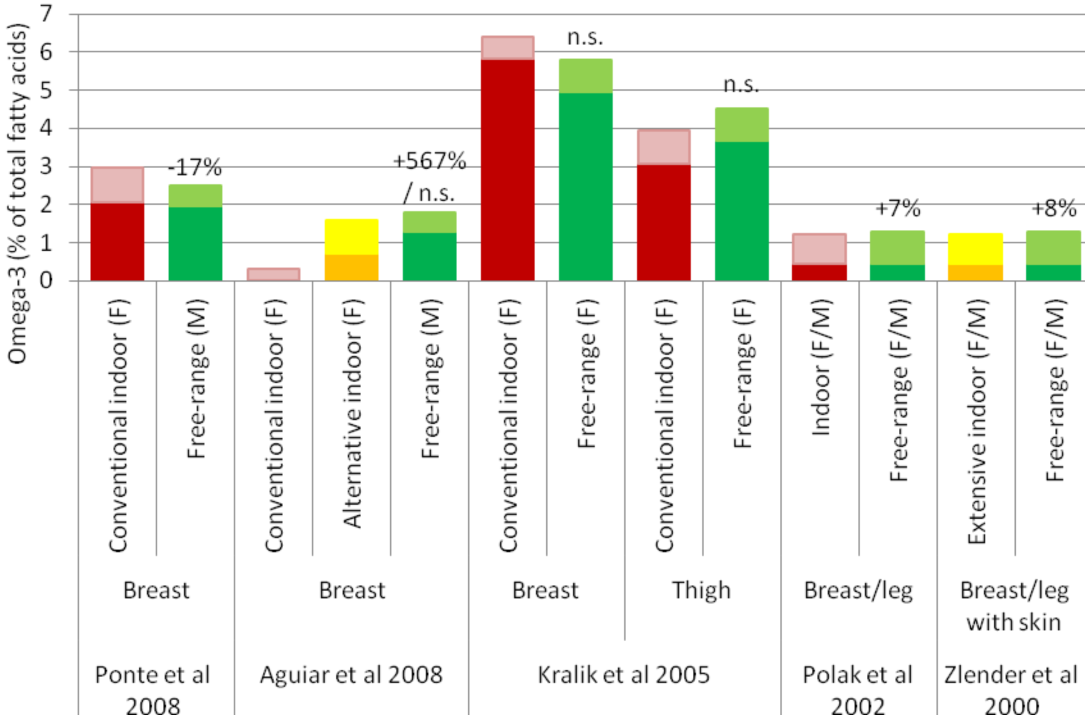
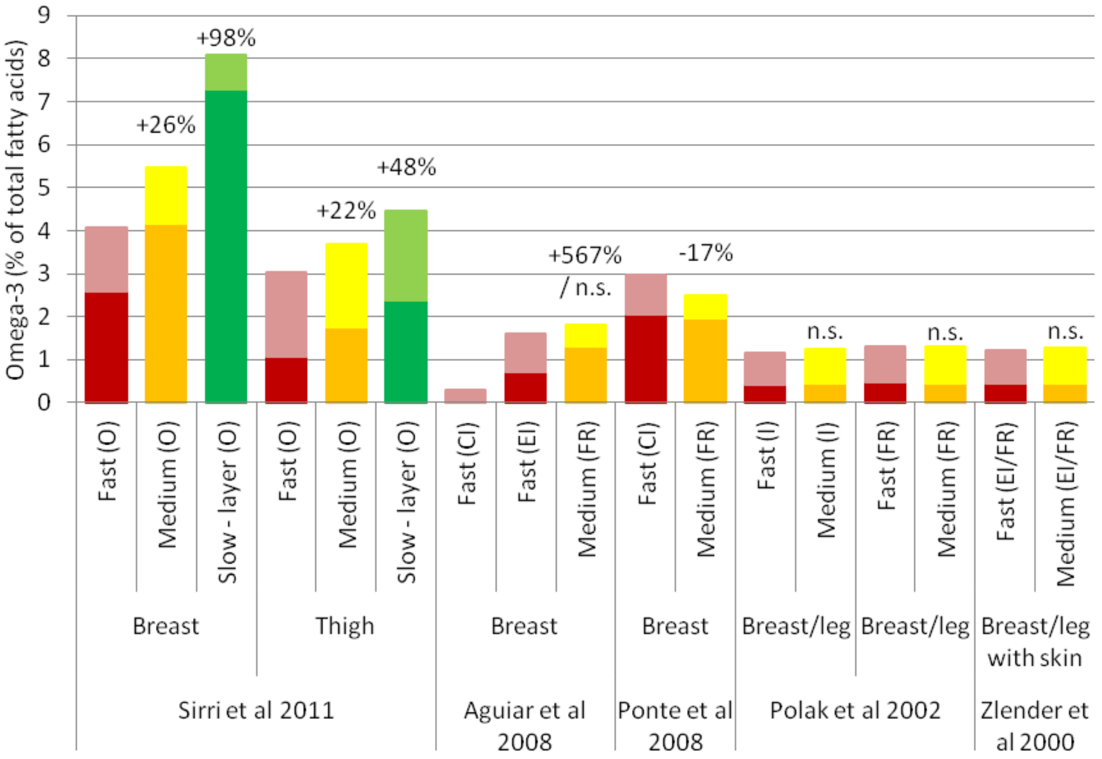


Figure 14. Omega-3 content and percentage difference between meat from fast-, medium- and slow-growing chicken genotypes. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. n.s. = difference not statistically significant. Production system indicated in parentheses as follows: I = indoor; CI = conventional indoor; EI = extensive indoor; FR = free-range; O = organic.



Based on the findings of Sirri *et al* (2011) mentioned in the previous paragraph, in order to obtain the same amount of long-chain omega-3 as would be found in a 100g serving of breast meat from a very slow-growing layer strain, a person would have to consume more than twice the quantity of breast meat from a fast-growing strain, which would involve consuming 2.7 times the quantity of fat (Table 2). Similarly, a person would have to consume around 38% more thigh meat of a fast-growing strain, which would involve consuming 2.2 times the quantity of fat (Table 2).

Table 2: Comparison of intramuscular fat and omega-3 levels in chicken meat from slow-growing and fast-growing strains reared organically. Based on Sirri *et al* (2011). For both meat types, total intramuscular fat content was significantly higher for the fast-growing genotype (P<0.05) and the proportion of omega-3 was significantly higher for the slower-growing genotype (P<0.01).

MEAT TYPE	**BREAST**		**THIGH**	
Chicken genotype (and rearing system)	**Slow-growing layer-type (organic)**	**Fast-growing meat-type (organic)**	**Slow-growing layer-type (organic)**	**Fast-growing meat-type (organic)**
Intramuscular fat (g/100g lean meat)	0.98	1.27	2.27	3.65
Long-chain omega-3 (mg/100g lean meat)	67	31	51	37
Product consumed to obtain the same amount of long-chain omega-3 as in 100g of product from slow-growing bird (g)		216		138
Fat consumed to obtain the same amount of long-chain omega-3 as in 100g of product from slow-growing bird (g)		2.74		5.04

Hundreds of millions of male layer chicks are killed at hatching in the EU every year because it is considered uneconomic to rear them for meat. Creating a premium market for these birds based on the nutritional qualities of the meat could potentially make it more economic to rear these birds, which would be highly desirable from an ethical point of view.

The quantities of long-chain omega-3 found in chicken meat are significant in terms of human nutritional requirements (see Section 3.2). Data from Australia indicate that consumption of chicken contributes an estimated 10% of total dietary intake of long-chain omega-3 (Howe *et al*, 2006). The findings presented here indicate that chicken meat from slower-growing strains, particularly very slow-growing layer strains, and from free-range and organic systems is generally more favourable in this respect.

The ratio of omega-6 to omega-3 is generally similar between chicken meat from free-range and indoor systems, ranging from 3.6 to 14.7 in free-range systems and from 3.0 to 15.0 in intensive systems (Ponte *et al*, 2008; Kralik *et al*, 2005; Polak *et al*, 2002; Zlender *et al*, 2000). The ratio of omega-6 to omega-3 is also generally similar between chicken meat from fast- and medium-growing strains, ranging from 5.8 to 14.8 in medium-growing strains and from 6.8 to 14.8 in fast-growing strains (Sirri *et al*, 2011; Ponte *et al*, 2008; Polak *et al*, 2002; Zlender *et al*, 2000). The ratio of omega-6 to omega-3 is significantly lower (4.3) in the beast meat of very slow-growing layer-type birds, reflecting the high levels of omega-3, particularly long-chain omega-3, in this meat (Sirri *et al*, 2011).

Ponte *et al* (2008) report no significant difference in vitamin E content between chicken meat from free-range and intensive systems. Castellini *et al* (2002a) report higher levels of vitamin E in the meat of slower-growing strains compared with a fast-growing strain, although the differences are not large (6.4% higher for a medium-growing meat strain and 10.5% higher for a slow-growing dual-purpose strain).

Iron content is higher for chickens reared in an organic system compared with an indoor system and for slower-growing strains compared with fast-growing strains (Fig. 15). The iron content of the organically-reared birds is between 19% and

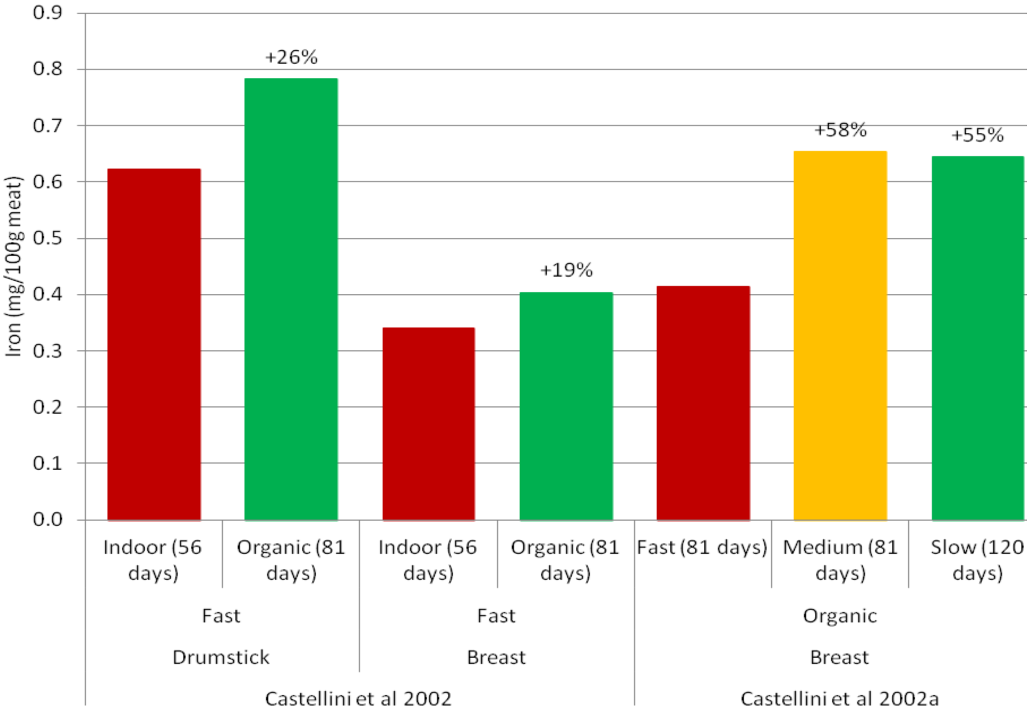
26% higher (for breast and drumstick respectively) compared with birds reared indoors. Iron content is between 55% and 58% higher for the breast meat of slower-growing strains (a dual-purpose slow-growing strain and a medium-growing strain, respectively) (Fig. 15). No data were available for a very slow-growing layer-type strain or for the drumstick meat of different strains.

A 100g serving of breast meat from a slower-growing bird reared organically provides around 0.65mg of iron, which is equivalent to 4.6% of the RDA (see Section 3.3). This compares with around 0.35mg of iron in a 100g serving of breast meat from a fast-growing strain reared indoors, which is equivalent to 2.5% of the RDA. For the drumstick, a 100g serving from a fast-growing strain reared organically provides almost 0.8mg, which is 5.7% of the RDA, compared with around 0.6mg for an indoor-reared bird, which is 4.3% of the RDA.

SUMMARY OF FINDINGS FOR CHICKEN MEAT

- Free-range and organic chicken meat contains less intramuscular fat than intensively-reared chicken meat;
- Chicken meat from slower-growing strains contains less fat than that from fast-growing strains;
- Free-range and organic chicken meat generally has a higher proportion of omega-3 fatty acids compared with intensively-reared chicken meat, with a similar ratio of omega-6 to omega-3;
- Chicken meat from medium-growing strains generally has a higher proportion of omega-3 fatty acids compared with fast-growing strains, with a similar ratio of omega-6 to omega-3;
- The meat of very slow-growing layer strains has a significantly higher proportion of omega-3 compared with fast- and medium-growing strains, and the breast meat of these birds has a lower ratio of omega-6 to omega-3 and is particularly rich in long-chain omega-3, including DHA;
- Levels of vitamin E are similar between chicken meat from free-range and intensive systems and are higher in the meat of slower-growing strains compared with fast-growing strains, although the differences are relatively small;
- Chicken meat from slower-growing strains and from birds reared organically contains more iron than meat from fast-growing strains and birds reared intensively, with higher welfare options providing around 5-6% of the adult RDA in a 100g serving.

Figure 15. Iron content and percentage difference between chicken meat from indoor and organic systems and from fast-, medium- and slow-growing genotypes at various slaughter ages.
n.s. = difference not statistically significant.



4.6 Eggs

Two studies have found higher levels of fat in free-range eggs (Anderson, 2011; Pignoli *et al*, 2009). However, most studies have found no significant difference in total fat content between free-range and battery eggs (Karsten *et al*, 2010; Hidalgo *et al*, 2008; Posadas Hernandez *et al*, 2005; Trziszka *et al*, 2004).

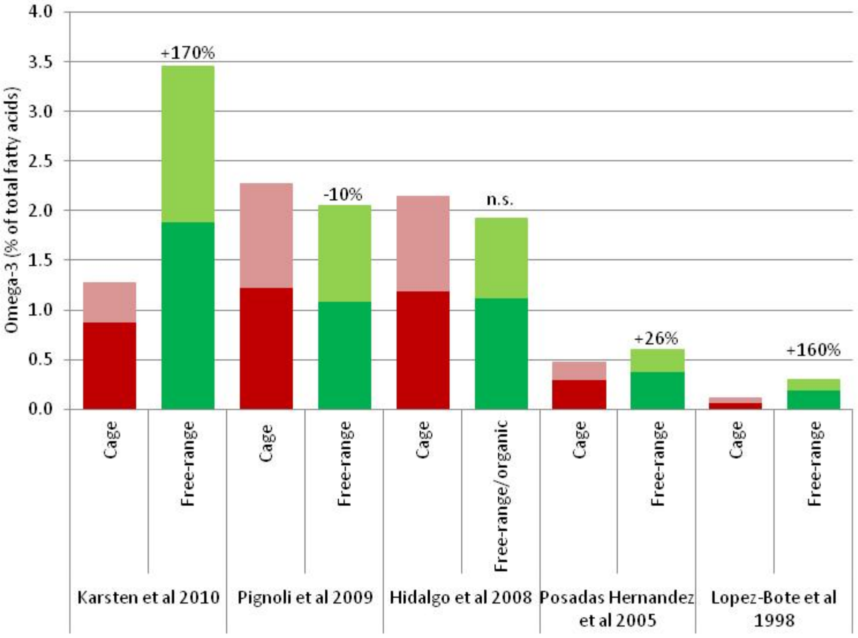
Most studies indicate the proportion of omega-3 is higher in free-range eggs compared with cage eggs, ranging from 26% to 170% more in free-range eggs (one study found no significant difference and one study found a 10% reduction in free-range eggs) (Fig. 16).

Two of the studies in Fig. 16 provide the necessary data to be able to calculate the actual amount of omega-3 in fresh egg yolk.[ix] In the Karsten *et al* (2010) study, the amounts are equivalent to 8.6mg/g yolk in free-range eggs, of which 4.7mg is long-chain omega-3, compared with 3.2mg/g yolk in cage eggs, of which 2.2mg is long-chain omega-3. In the Posadas-Hernandez *et al* (2005) study, the amounts are equivalent to 1.22mg/g yolk in free-range eggs, of which 0.78mg is long-chain omega-3, compared with 1.16mg/g yolk in cage eggs, of which 0.75mg is long-chain omega-3.

In some cases, levels of omega-3 may be much higher in free-range eggs. For example, Simopoulos & Salem (1991)[x] report levels of omega-3 in the yolk of Greek free-range eggs of 17.7mg/g, of which 10.6mg is long-chain omega-3 (including 6.6mg of DHA). This is equivalent to 265mg of long-chain omega-3 (including 165mg of DHA) in a single egg, making it an excellent terrestrial source of long-chain omega-3, including DHA. These hens fed on pasture that included a plant that is particularly rich in omega-3 (purslane). By comparison, the same study found the yolk of cage eggs purchased in the US contained 1.7mg/g omega-3, including 1.2mg long-chain omega-3, equivalent to 30mg long-chain omega-3 in a single egg.

Most studies indicate that free-range eggs have a lower ratio of omega-6 to omega-3 fatty acids compared with battery eggs (Karsten *et al*, 2010; Trziszka *et al*, 2004; Lopez-Bote *et al*, 1998; Simopoulos & Salem, 1991). Two studies found no significant difference (Pignoli et al, 2009; Hidalgo et al, 2008). The omega-6 to omega-3 ratio is between 1.3 and 14.1 for free-range and organic eggs and between 11.2 and 19.9 for battery cage eggs.

Figure 16. Omega-3 content and percentage difference between eggs from battery cages and free-range/organic systems. The lower (darker shaded) section of each bar represents long-chain (≥20 carbons) omega-3. The upper (lighter shaded) section of each bar represents 18-carbon omega-3. n.s. = difference not statistically significant.



[ix] Based on a conversion factor of 0.830 to give total fatty acids in fat in eggs (from MAFF, 1998).

[x] Data not presented in Fig. 16 because figures for omega-3 were reported in mg/g egg yolk rather than as a proportion of fatty acids and total fat contentment of the eggs was not reported to allow conversion.

A number of studies have found higher levels of vitamin E in free-range eggs compared with cage eggs. Karsten *et al* (2010) found twice the amount of vitamin E in free-range eggs, whilst Lopez-Bote *et al* (1998) found 31% more vitamin E in free-range eggs. However, others have found no significant difference (Anderson, 2011; Pignoli *et al*, 2009). The quantities of vitamin E in egg are significant in terms of human nutritional requirements (see Section 3.2). Lopez-Bote *et al* (1998) report that egg yolk contains 8.6mg and 6.6mg per 100g for free-range and cage eggs respectively. Assuming the contents of an average egg weigh around 50g and that 35% of this is yolk (Ahn *et al*, 1997) this is equivalent to 3mg per 100g (2 eggs) serving of free-range eggs and 2.3mg per 100g (2 eggs) serving of cage eggs. This is equivalent to 25% and 19% of the RDA, respectively. Anderson *et al* (2011) report that free-range eggs contain 281% more beta-carotene than cage eggs. Also, Pignoli *et al* (2009) report that free-range eggs contain 12% more lutein than cage eggs.

No data were available to compare levels of iron between free-range/organic eggs and battery cage eggs.

Summary of findings for eggs:

- There are no consistent differences in total fat content between eggs from free-range or organic systems and eggs from battery cages;
- Free-range and organic eggs generally have a higher proportion of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 compared with battery cage eggs;
- Some free-range eggs are a particularly rich source of long-chain omega-3, including DHA;
- Free-range eggs often contain more antioxidants (vitamin E, beta-carotene and lutein) compared with battery cage eggs and are a rich source of vitamin E.

Salmon and trout

The total fat content is generally between 38% and 60% lower in wild-caught salmon compared with farmed salmon (two studies found no significant difference) (Fig. 17). The total fat content is generally between 23% and 82% lower in wild-caught trout compared with farmed trout (two studies found no significant difference) (Fig. 18).

Figure 17. Total fat content and percentage difference between farmed and wild salmon.
n.s. = difference not statistically significant.

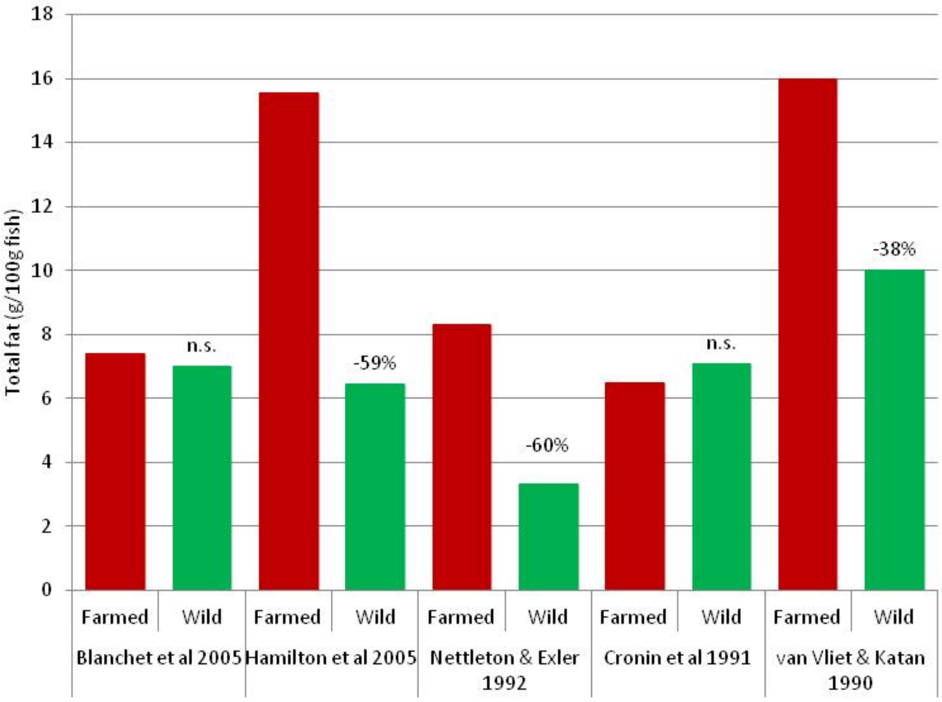
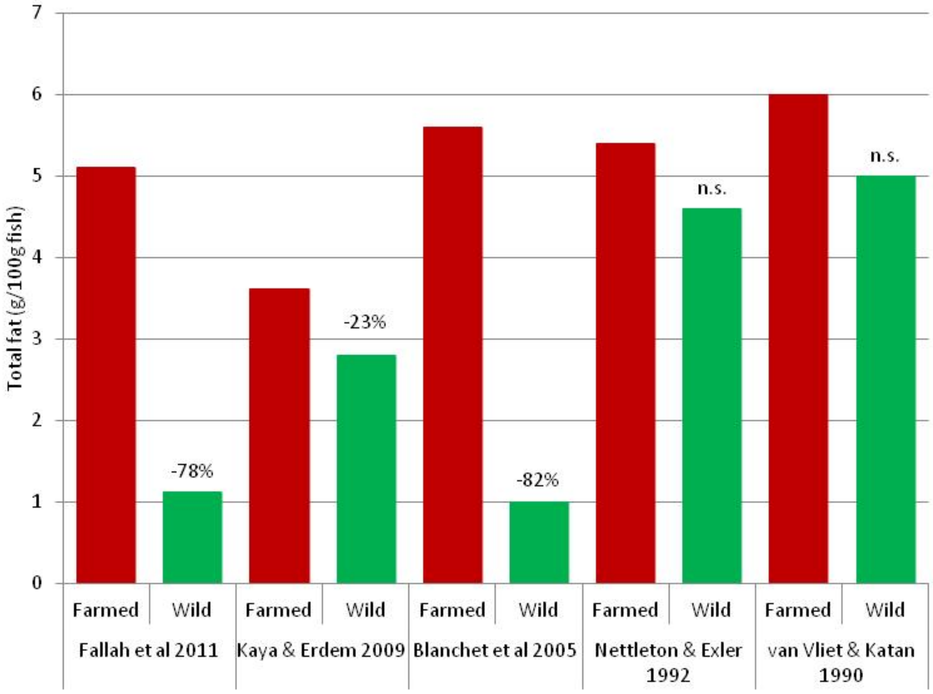


Figure 18. Total fat content and percentage difference between farmed and wild trout.
n.s. = difference not statistically significant.



Both wild and farmed salmon are rich in long-chain omega-3 fatty acids and there are no consistent differences in the proportion of omega-3 fatty acids between wild and farmed salmon. One study reports higher levels in farmed salmon (Blanchet *et al*, 2005), whilst one study reports higher levels in wild salmon (Cronin *et al*, 1991), and another reports no significant difference (although the proportion of DHA was significantly higher in the wild salmon in this study) (van Vliet and Katan, 1990). Long-chain omega-3 fatty acids make up between 16% and 28% of total fatty acids in farmed salmon and between 18% and 24% in wild salmon (Blanchet *et al*, 2005; Cronin *et al*, 1991; van Vilet and Katan, 1990).

Both wild and farmed trout are also rich in long-chain omega-3 fatty acids. However, the proportion of omega-3 fatty acids is between 43% and 66% higher in wild trout (Fig. 19).

The proportions of long-chain omega-3 in salmon and trout are equivalent to between 300mg and 3000mg in a 100g serving of fish.[xii] Generally, between half and three-quarters of the long-chain omega-3 in salmon and trout is DHA, making it an excellent source both of long-chain omega-3 in general and DHA specifically.

The ratio of omega-6 to omega-3 is relatively low (<1) for both wild and farmed salmon and trout. However, this ratio is significantly lower for wild salmon and trout compared with their farmed counterparts. The ratio of omega-6 to omega-3 is between 47% and 84% lower for wild salmon compared with farmed salmon (Fig. 20). Similarly, the omega-6 to omega-3 ratio is generally between 55% and 72% lower for wild trout compared with farmed trout (in one study the difference is not statistically significant) (Fig. 21). Given that the ratio between these groups of fatty acids is likely to be important, in addition to the actual amount of omega-3, and that modern Western diets are often relatively deficient in omega-3 with a relative excess of omega-6 (see Section 2.1), wild salmon and trout would be considered more favourable in contributing to achieving a more balanced ratio of these fatty acids in the diet than their farmed counterparts.

Fallah *et al* (2011) report that wild trout contains twice the quantity of iron compared with farmed trout: 0.7mg vs 0.3mg per 100g serving. This is equivalent to 5% and 2.4% of the RDA respectively.

No data were available to compare levels of antioxidants between wild and farmed fish.

[xii] Based on a conversion factor of 0.900 to give total fatty acids in fat in oily fish (from MAFF, 1998).

Figure 19. Omega-3 content and percentage difference between farmed and wild trout.

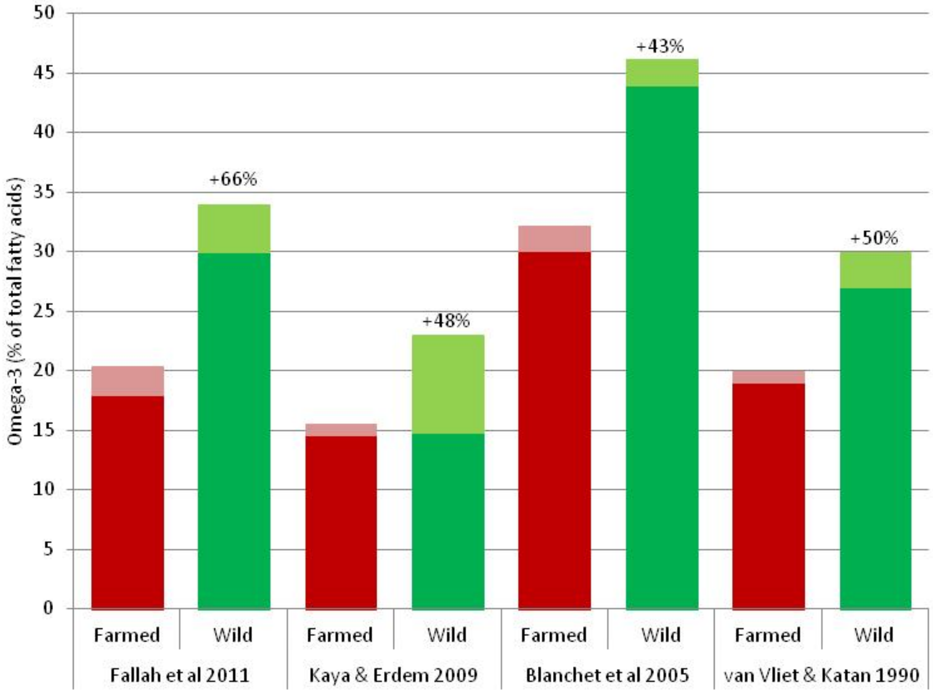


Figure 20. Ratio of omega-6 to omega-3 fatty acids and percentage difference between farmed and wild salmon.

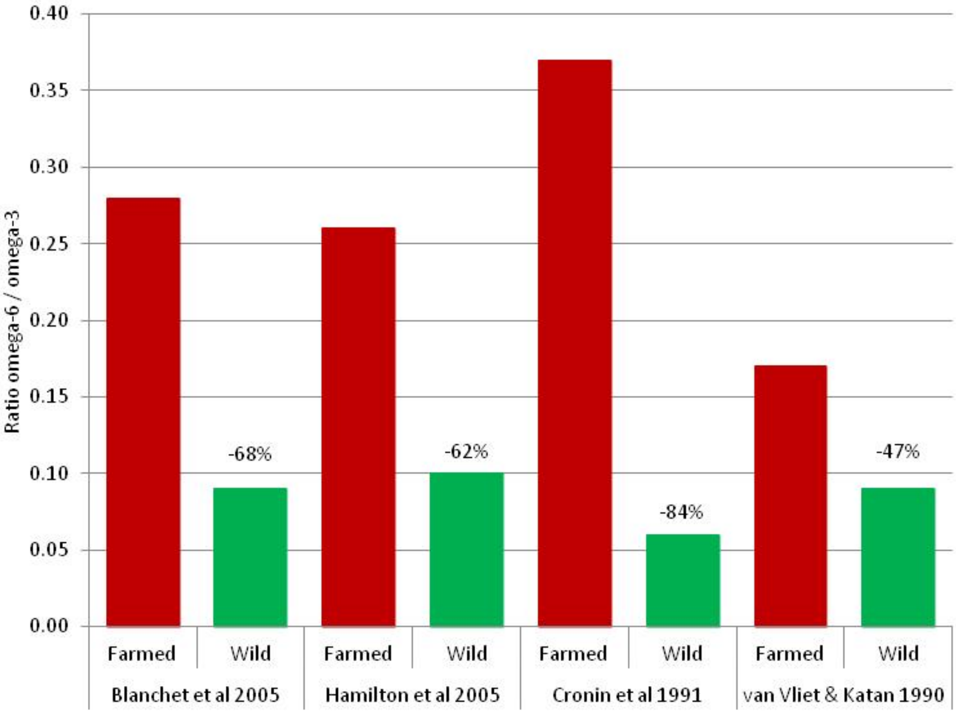
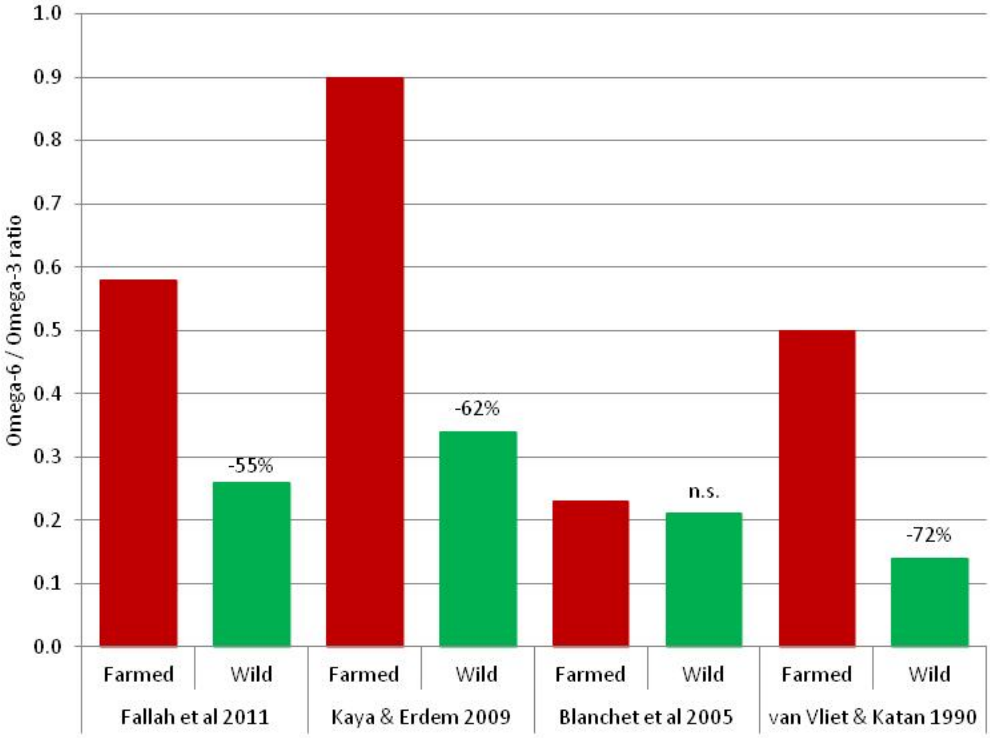


Figure 21. Ratio of omega-6 to omega-3 fatty acids and percentage difference between farmed and wild trout. n.s. = difference not statistically significant.



Summary of findings for salmon & trout:

- Wild salmon and trout contain less fat than farmed salmon and trout;
- Both wild and farmed salmon and trout contain a high proportion of omega-3 fatty acids and can make a substantial contribution to meeting nutritional requirements for long-chain omega-3 fatty acids, including DHA;
- Wild trout contains a higher proportion of omega-3 fatty acids compared with farmed trout;
- All salmon and trout have a relatively low (generally <1) ratio of omega-6 to omega-3 but this ratio is lower for wild salmon and trout compared with farmed salmon and trout, which could be beneficial in contributing to a more balanced ratio of these fatty acids in the diet;
- Wild trout contains more iron than farmed trout, with around 5% of the adult RDA in a 100g serving.

5. Summary of findings for each nutrient group

Total fat

Pasture-reared beef contains between 25% and nearly 50% less intramuscular fat compared with intensively-reared beef. Free-range and organic chicken often contains less intramuscular fat than intensively-reared chicken, in some cases as much as 50% less. Meat from slower-growing chicken breeds also contains less intramuscular fat than fast-growing breeds: Generally around 10-30% less for medium-growing strains and around 20-65% less for slow-growing strains. Wild salmon generally contains between 40% and 60% less fat than farmed salmon and wild trout generally contains between 25% and 80% less fat than farmed trout.

There were no consistent differences in total fat content between higher-welfare and lower-welfare production systems for lamb, milk, pig meat or eggs.

Omega-3

For all of the terrestrial animal products, the proportion of omega-3 is generally greater and the ratio of omega-6 to omega-3 is more favourable (lower) in the higher-welfare products. For fish, the proportion of omega-3 is greater for wild trout compared with farmed trout and is similar between wild and farmed salmon. For both salmon and trout, the ratio of omega-6 to omega-3 is lower for the wild fish compared with the farmed fish.

The amounts of shorter-chain omega-3 in the animal products examined are likely to make only a relatively minor contribution to human dietary intake, being generally below 100mg per 100g or 100ml of product (except that some free-range eggs may have higher levels but still below 200mg per 100g of whole egg). For comparison, 100g of walnuts provides 7470mg of shorter chain omega-3 (ALA) (FSA, 2002).

For long-chain omega-3, several of the animal products examined can make a substantial contribution to meeting human nutritional requirements, particularly salmon and trout (both wild and farmed), pasture-reared lamb and beef, higher-welfare chicken meat (especially from very slow-growing layer-type strains) and some free-range eggs. Levels of long-chain omega-3 can be from tens to hundreds of mg per 100g in the terrestrial products and from hundreds to thousands of mg per 100g in the fish.

In terms of DHA specifically, salmon and trout (both wild and farmed) contain substantial amounts of DHA, and some higher-welfare eggs, chicken and lamb also contain appreciable amounts.

Antioxidants

Comparative data for vitamin E content are available for beef, milk, pig meat, chicken meat and eggs. Vitamin E levels are between 35% and 160% higher for beef from pasture-based systems compared with intensive systems, between 25% and 60% higher for milk from pasture-based systems compared with conventional systems and generally between 25% and 200% higher for free-range pig meat compared with intensively-reared pig meat. For chicken, there is no significant difference in vitamin E content between chicken meat from free-range and intensive systems and the meat of slower-growing strains contains a little (up to around 10%) more than fast-growing strains. For eggs, some studies show between one third and twice as much vitamin E in free-range eggs compared with cage eggs. However, in some studies the difference is not significant.

The amount of vitamin E in a 100g serving of higher-welfare beef or pig meat is between 0.2mg and 0.6mg, which is equivalent to between 2% and 5% of the adult RDA, and would therefore be expected to make a modest contribution to human dietary intake. The amount of vitamin E in milk is lower (equivalent to around 0.5-1% of the adult RDA). The amount of vitamin E in free-range eggs is around 3mg per 100g (2 eggs) serving. This is equivalent to around 25% of the RDA and would therefore be expected to make a significant contribution to human dietary intake. For comparison, 100g of walnuts provides around 4mg of vitamin E and 100g of almonds provides around 24mg of vitamin E (*Ibid.*)

Comparative data for beta-carotene content are available for beef, milk and eggs. In most cases, levels of beta-carotene are several hundred percent higher in the higher-welfare products. However, the total amounts are relatively low in terms of human dietary intake, being generally below 150µg per 100g or 100ml of product, which is equivalent to less than 1.5% of the adult RDA for vitamin A. For comparison, 100g of raw carrots provides over 10 000µg of beta-carotene (*Ibid.*), which is sufficient to provide 100% of the RDA for vitamin A.

Iron

Comparative data for iron content are available for pig meat, chicken meat and trout. Iron levels are over three times higher in free-range pig meat compared with intensively-reared pig meat, over 50% higher for meat from slower-growing chicken strains compared with fast-growing strains, around 20-25% higher for organic chicken compared with intensively-reared chicken, and twice as high for wild trout compared with farmed trout.

The amount of iron in a 100g serving of the higher-welfare products is between 0.5mg and 0.8mg, equivalent to between 4% and 6% of the adult RDA, and would therefore be expected to make a moderate contribution to human dietary intake. For comparison, 100g of baked beans contains 1.4mg of iron (*Ibid.*). However, much of the iron in animal products (between 30% and 70%) is in the form of haem iron, which is more easily absorbed by the body (Strain and Cashman, 2009). The absorption of non-haem iron from plant sources is dependent to a large extent upon the presence of facilitating and inhibiting substances in the meal and on the iron status of the individual (*Ibid.*).

Table 3: Summary of nutritional differences between higher-welfare and lower-welfare animal products. The direction of arrows in the left hand column indicates whether a higher or lower value is generally considered beneficial. ↑ or ↓ indicate where higher-welfare products typically have a more favourable nutritional composition (higher or lower levels respectively) compared with intensively-produced products. ↔ indicates no consistent difference between higher-welfare and lower-welfare products. - indicates no comparative data available.

	Lamb	Beef	Milk	Pig meat	Chicken meat	Eggs	Salmon/ Trout
Total fat ↓	↔	Pasture-based ↓	↔	↔	Slower-growing & free-range/ organic ↓	↔	Wild ↓
Proportion of omega-3 ↑	Pasture-based ↑	Pasture-based ↑	Pasture-based ↑	Free-range/ organic ↑	Slower-growing & free-range/ organic ↑	Free-range/ organic ↑	Trout - wild ↑ Salmon ↔
Proportion of long-chain omega-3 ↑	Pasture-based ↑	Pasture-based ↑	Pasture-based ↑	Free-range/ organic ↑	Slower-growing & organic ↑	Free-range/ organic ↑	Wild ↑
Omega-6/ Omega-3 ratio ↓	Pasture-based ↓	Pasture-based ↓	Pasture-based ↓	Free-range/ organic ↓	Very slow-growing ↓	Free-range/ organic ↓	Wild ↓
Vitamin E ↑	-	Pasture-based ↑	Pasture-based ↑	Free-range ↑	Slower-growing ↑	Free-range ↑	-
Carotenoids ↑	-	Pasture-based ↑	Pasture-based ↑	-	-	Free-range ↑	-
Iron ↑	-	-	-	Free-range ↑	Slower-growing & organic ↑	-	Trout - wild ↑ Salmon -

6. Conclusions

Higher-welfare animal products were shown to have a number of nutritional benefits over intensively-reared animal products.

Excessive fat consumption can contribute to weight gain and associated health problems. Higher-welfare animal products are often significantly lower in fat than equivalent products from intensively-reared animals. This is true of pasture-reared beef, free-range and organic chicken and chicken of slower-growing breeds, and wild salmon and trout.

Choosing higher-welfare animal products over intensively-reared animal products would be expected to be beneficial in reducing dietary intake of fat, including saturated fat.

Modern western diets are often deficient in omega-3 fatty acids and have excessive amounts of omega-6 fatty acids relative to the amount of omega-3. An adequate intake of long-chain (≥20 carbon atoms) omega-3 fatty acids is particularly important for brain and heart health. Compared with intensively-farmed animal products, higher-welfare animal products typically have higher levels of omega-3 fatty acids and a more favourable (lower) ratio of omega-6 to omega-3 fatty acids. Wild salmon and trout, pasture-reared lamb and beef, chicken meat from slow-growing layer-type strains and some free-range eggs are particularly beneficial in this respect.

Choosing higher-welfare animal products over intensively-reared animal products would be expected to make a substantial contribution to meeting dietary requirements for long-chain omega-3 fatty acids and achieving a more balanced intake of omega-6 and omega-3 fatty acids.

Higher-welfare animal products often contain higher levels of antioxidants, such as vitamin E and beta-carotene, and higher levels of iron, compared with intensively-produced animal products.

Choosing higher-welfare animal products over intensively-reared animal products would be expected to make a moderate contribution to meeting dietary requirements for vitamin E and iron.

Limitations and further research

Issues with the data

Direct comparison of data between studies cannot necessarily be made because of the widely varying approaches taken in the preparation of samples and methodology of the nutrient analyses. Therefore, whilst comparisons within a study are valid, differences between one system or breed in one study and a different system or breed in another study may not be. In some cases, studies were excluded from the analysis because the data were collected or presented in such a way that it was not possible to find a common approach.

Within studies, comparison of data from different systems is often challenging because animals may mature at different rates. For example, cattle finished at pasture generally take significantly longer to reach slaughter weight than those finished intensively. Similarly, chickens of slower-growing breeds will generally be significantly older at slaughter than their fast-growing counterparts. Some studies compared animals slaughtered at the same age, whilst others compared animals slaughtered at a similar weight. In many cases therefore, it is difficult to determine whether differences in nutritional content are a result of the system per se or a result of the differing ages and/or weights of the animals being compared. Some studies compared both combinations of same age/different weight and same weight/different age. In these cases, the data most representative of commercial practice (i.e. usually the same weight) were used.

Issues with the production systems

The actual level of welfare attained in any production system is dependent not only on the welfare potential of the production system but also on the level of management skill applied to it. Since the studies used in this analysis did not measure welfare directly in the systems compared, the welfare potential of the systems is used as a proxy for the level of welfare experienced by the animals.

In some studies, the production systems are not clearly defined, which may partially mask nutritional differences between systems. For example, several of the studies for milk compared conventional retail or bulk milk with organic milk. Conventional milk may include milk from a range of systems, including those using grazing to varying extents. The presence of milk from pasture-based systems in the samples of conventional milk could potentially reduce nutritional differences between these and the organic milk samples.

Similarly, for studies comparing chicken from slower-growing breeds with conventional fast-growing breeds, the actual and potential growth rate of the slower-growing strains is not always clearly defined. A breed that may be considered slow-growing in one study may be considered to be a medium-growing strain in another study that includes a strain with an even slower growth rate. To avoid any confusion, all slower-growing broiler (meat) strains were classified as medium-growing strains for the purposes of this study in order to distinguish them from the significantly slower-growing dual-purpose and layer strains. This means that there is actually quite a wide variation in growth rate for the birds classified as medium-growing.

Issues with the nutrients covered by the analysis

There may be many other nutrients that differ between higher- and lower-welfare animal products but the scope of the analysis was limited by the availability of data in the scientific literature. For those that were included, in some cases the findings for certain nutrients and products are based on very limited data. For example, the findings of Sirri *et al* (2011) in relation to the omega-3 content of chicken meat from a slow-growing layer strain (compared with fast-growing and medium-growing broiler strains) are intriguing and suggest that rearing the males of layer strains for meat may produce meat with significant nutritional advantages. However, this is only one study and further research is needed to confirm these findings.

Other nutrients were excluded from the analysis because of a lack of conclusive evidence of their health effects. For example, conjugated linoleic acid (CLA) is a collective term for a group of positional and geometric isomers of linoleic acid. Naturally-occurring CLA is found primarily in the milk and meat of ruminants and is mostly of the *cis*-9, *trans*-11 configuration. CLA has been shown to have a beneficial effect on cancer, cardiovascular disease, diabetes, body composition, the immune system and bone health Schmid *et al*, 2006). However, data mainly derive from animal trials and the findings from human trials have so far been inconclusive (*Ibid.*). Many studies have already been conducted investigating the levels of CLA in animal products from different production systems and it appears that levels are generally significantly higher in animals kept at pasture. If the health benefits of CLA are confirmed in humans, an analysis of the findings of these studies would be warranted.

GLOSSARY

Nutrient	Acronym	Description	Recommended intake
Alpha-linolenic acid	ALA	Shorter-chain omega-3 fatty acid (18 carbon atoms; 3 double bonds) – the parent of the omega-3 family of fatty acids that is essential in the diet because it cannot be made in the body	EFSA NDA Panel[xii] recommends an adequate intake equivalent to 0.5% of total energy (EFSA, 2010)
Alpha-tocopherol		The most biologically active form of vitamin E	RDA[xiii] (EU) for vitamin E = 12mg/day
Antioxidants		Naturally occurring compounds that can neutralise free radicals (highly reactive molecules that damage body cells)	No RDA set
Arachidonic Acid	AA	Long-chain omega-6 fatty acid (20 carbon atoms; 4 double bonds)	No RDA set
Beta-carotene		Antioxidant and provitamin A carotenoid	No RDA set for beta-carotene. RDA (EU) for vitamin A = 800μg/day, which is equivalent to 9600μg beta-carotene
Carotenoids		Antioxidants, some of which can be converted into vitamin A in the body	No RDA set
Docosahexaenoic acid	DHA	Long-chain omega-3 fatty acid (22 carbon atoms; 6 double bonds)	Various sources recommend around 200-500mg per day of EPA and DHA combined (EFSA, 2010; Harris *et al*, 2009); EFSA NDA Panel recommends an additional 100-200mg/day of pre-formed DHA during pregnancy and lactation (EFSA, 2010)
Docosapentaenoic acid	DPA	Long-chain omega-3 fatty acid (22 carbon atoms; 5 double bonds)	No RDA set
Eicosapentaenoic acid	EPA	Long-chain omega-3 fatty acid (20 carbon atoms; 5 double bonds)	Various sources recommend around 200-500mg per day of EPA and DHA combined (EFSA, 2010; Harris *et al*, 2009)
Iron		Essential mineral	RDA (EU) = 14mg/day
Linoleic acid	LA	Shorter-chain omega-6 fatty acid (18 carbon atoms; 2 double bonds) – the parent of the omega-6 family of fatty acids that is essential in the diet because it cannot be made in the body	EFSA NDA Panel recommends an adequate intake equivalent to 4% of total energy (EFSA, 2010)
Lutein		Antioxidant	No RDA set
Monounsaturated fatty acids	MUFA	Fatty acids with one double bond	No RDA set for total MUFA but replacement of SFA in the diet with a mixture of PUFA and MUFA is considered beneficial (EFSA, 2010)
Omega-3 fatty acids		A family of polyunsaturated fatty acids where the first double bond occurs after the third carbon atom from the methyl end	See separate recommendations for ALA, EPA and DHA

[xii] European Food Safety Authority Panel on Dietetic Products, Nutrition and Allergies.

[xiii] Recommended Daily Allowance.

Omega-6 fatty acids		A family of polyunsaturated fatty acids where the first double bond occurs after the sixth carbon atom from the methyl end	See recommendation for LA
Polyunsaturated fatty acids	PUFA	Fatty acids with two or more double bonds	No RDA set for total PUFA but replacement of SFA in the diet with a mixture of PUFA and MUFA is considered beneficial (EFSA, 2010) – see separate recommendations for LA, ALA, EPA and DHA
Provitamin A carotenoids		Carotenoids that can be converted into vitamin A in the body	RDA (EU) for vitamin A = 800µg/day
Saturated fatty acids	SFA	Fatty acids with no double bonds (i.e. where all the carbon atoms are bonded to their full complement of hydrogen atoms)	EFSA NDA Panel recommends less than 10% of energy intake (or as little as possible within the context of a nutritionally adequate diet) should come from SFA (EFSA, 2010)
Unsaturated fatty acids	UFA	Fatty acids with one or more double bonds – includes monounsaturated fatty acids and polyunsaturated fatty acids	No RDA set for total UFA but replacement of SFA in the diet with a mixture of PUFA and MUFA is considered beneficial (EFSA, 2010) – see separate recommendations for LA, ALA, EPA and DHA
Vitamin E		Essential vitamin which acts as an antioxidant	RDA (EU) = 12mg/day

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