Balancing health and sustainability

The role of red meat in the UK diet

Foreword

Internationally, there is a consensus that food systems need to be transformed to help tackle environmental sustainability, malnutrition in all its forms and food insecurity. These challenges highlight the critical importance of advocating for, and adhering to, healthy and sustainable diets.

Central to this effort is red meat – a long-standing dietary staple that raises contentious environmental, health and ethical debate. However, recent research shows that when paired with plant-rich foods, animal-sourced foods such as red meat can support balanced, healthy and sustainable diets.

This report analyses red meat's multidimensional role in UK diets, focusing on health and sustainability. It reviews current scientific evidence on its nutritional composition, dietary contributions and impact on health. Additionally, it examines the implications of red meat production for food systems and environmental sustainability, highlighting UK farmers progress towards more sustainable practices.

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Executive summary

1. Introduction – Food systems and the role of sustainability and nutrition

- To tackle climate change, food security and public health, we need a balanced approach that values red meat's nutritional benefits and promotes sustainable farming. By encouraging sustainable diets and improving agricultural practices, we can protect human and planetary health for future generations
- A sustainable healthy diet is vital for health and the environment, and it must be accessible, affordable, safe, equitable and culturally acceptable. The UK's Eatwell Guide outlines a framework for this, recommending moderate red and processed meat consumption within a diverse, plant-rich diet to support health and environmental goals
- Red meat is a valuable source of high-quality protein and essential micronutrients, especially during key life stages. However, excessive intake, particularly of processed varieties, is linked to an increased risk of non-communicable diseases such as cancer. Balancing red meat consumption is therefore crucial to maximise health benefits while minimising potential health risks
- Although UK livestock contributes to 7% of national greenhouse gas emissions, it is significantly lower than emissions from the energy (electricity and fuel – 22%) and transport (28%) sectors. Reaching net zero in the UK by 2050 requires advancements in agricultural practices, such as feed efficiency, grassland management and genetic advancement, alongside improving carbon sequestration, enhancing soil health and improving energy efficiency. Accurate measurement and baseline analysis of environmental metrics are crucial for managing emissions, ensuring food security and providing high-quality nutritious food

2. Red meat – UK dietary recommendations, guidance, consumption and purchasing

- Despite the growing scientific evidence on sustainable food systems, nutritional quality, local diet composition and nutrient delivery to all age groups are often overlooked in recommendations for healthier and lower-environmental-impact diets
- Global food-based dietary guidelines (FBDGs) are increasingly advocating reduced red and processed meat consumption for health and sustainability. However, excessive reductions may pose health risks if not carefully managed. The UN has not established specific targets, but the UK's Eatwell Guide recommends limiting red and processed meat to 70 g per day due to links with colorectal cancer. Following the Eatwell Guide can provide both environmental and health benefits
- Data from the National Diet and Nutrition Survey shows that average red and processed meat consumption in the UK is within recommended limits, but it varies by age and gender, with younger men consuming more. Strategies should aim to guide high-meat consumers (those eating >90 g

per day) towards balanced diets by following the Eatwell Guide and increasing fruit, vegetables and fibre while reducing saturated fat, salt and sugar

- UK household purchasing data reveals a decline in red meat consumption but increases in white meat, as well as processed meats and convenience foods that contribute significantly to saturated fat and salt intake. Understanding the role of these foods and red meat in non-communicable disease risk is complex. Clear distinctions between processed and red meat in dietary guidelines and research would enhance public health messaging, improve health risk assessments and help consumers make informed dietary choices
- Studies indicate that substantial reductions in meat intake can lead to deficiencies in micronutrients, such as iron, zinc and vitamin B12, particularly in women of reproductive age and those who are already nutritionally compromised. For this reason, a blanket meat reduction message could lead to unintended detrimental health consequences
- Nutrition is essential in discussions around transforming food systems; without it, we risk promoting environmentally beneficial dietary changes that may be unrealistic, potentially leading to nutritional deficiencies and increased public health burdens

3. Nutritional contribution of red meat consumption to UK diets over the life course

- Red meat is nutritionally dense, providing a concentrated source of essential nutrients, such as high-quality protein, bioavailable iron, zinc and vitamin B12. Unlike plant-based proteins, which require a variety of sources to provide all essential amino acids, animal proteins deliver them all. High-quality protein is especially important for maintaining muscle mass and function as we age
- Although red meat contains saturated fat, it is also a good source of beneficial monounsaturated and polyunsaturated fats. Grass-fed practices can enhance the nutritional quality of red meat by increasing omega-3 fatty acids and essential nutrients such as amino acids and iron. To reduce cardiovascular disease risk, it is advised to choose lean cuts of red meat, limit processed meat and boost fruit, vegetable and dietary fibre intake
- Red meat is a key source of vitamin B12, iron, zinc and selenium, vital for energy production, immune function and reproductive health. These nutrients are especially important for vulnerable groups, including women of childbearing age, adolescents and older adults. For instance, nearly 50% of adolescent girls have iron intake below recommended levels, risking iron deficiency anaemia that can impact growth and cognitive development. Including iron-rich foods such as red meat is crucial for addressing these nutritional gaps
- Red meat is vital for nutrition across the life course. During pregnancy and lactation, it provides essential nutrients including iron and vitamin B12 for maternal health and foetal and postnatal development. For infants and young children, it supplies iron, zinc and protein, crucial for growth and cognitive function. In older adults, sufficient protein from red meat helps maintain muscle mass, supports immune function and prevents nutrient deficiencies, promoting healthy ageing
- These points clearly highlight the importance of including red meat as part of a balanced diet, for its essential nutrients that support overall health, especially in populations with higher nutritional

needs. While moderation is key, red meat is a valuable component of a nutrient-rich diet, which promotes health and wellbeing across life stages

4. Role of red meat on health and non-communicable disease risk

- The World Health Organization emphasises that a healthy diet is essential for preventing malnutrition and non-communicable diseases (NCDs), such as diabetes, heart disease, stroke and cancer. In the UK, rising NCD rates are largely driven by unhealthy diets, obesity and low physical activity. Following the Eatwell Guide, which recommends at least five portions of fruits and vegetables and 30 g of fibre daily, can significantly reduce NCD risk
- Observational studies link red and processed meat consumption to higher risks of colorectal cancer, cardiovascular disease (CVD) and type 2 diabetes (T2D). However, stronger evidence from randomised controlled trials (RCTs) often fails to confirm these associations
- Early research labelled red meat a 'convincing cause' of colorectal cancer, but further evidence downgraded it to a 'probable cause', and processed red meat remains a strong risk factor. This supports the recommendation to limit red and processed meat to 70 g per day, – a guideline maintained since the World Cancer Research Fund and American Institute of Cancer Research's last update in 2018
- Processed meat shows a stronger link to increased CVD risk than red meat, but RCT evidence is inconclusive. Similarly, while observational studies suggest red meat may increase T2D risk, RCTs do not consistently support this. These discrepancies emphasise the need for more robust long-term research to clarify the relationships between meat consumption and these diseases for accurate dietary guidelines
- Evidence suggests red meat purchasing and consumption in the UK is declining in favour of white meat. However, consumption of processed meat and convenience foods high in saturated fat, salt and sugar linked to unhealthy behaviours and a higher risk of NCDs is also increasing. Understanding the role these foods play alongside red meat in NCD risk is complex
- Addressing NCD risks requires a comprehensive approach that extends beyond reducing meat consumption. It involves promoting healthier eating patterns, increasing physical activity and tackling socioeconomic inequalities. Interventions should focus on reducing high meat consumption (>90 g per day) and encouraging balanced diets, as per the Eatwell Guide, aiming to improve health outcomes and support environmental sustainability

5. Farming practices and the production of red meat in the UK

- Agriculture is a source of both carbon emissions and carbon sequestration, and yet they are accounted for separately. It is critical that we look at the whole farm when assessing net carbon positions – accounting for both their carbon emissions and the carbon sequestration and storage that they provide, and that the net position flows through into reporting mechanisms, such as the national inventory and product footprints

- UK farms are already embracing practices and technologies that enable them to mitigate greenhouse gas emissions from farming systems, alongside managing existing carbon stocks and optimising on-farm carbon sequestration
- The UK livestock sector is taking a proactive 'no-regret' approach, taking action to address mitigations that are cost-effective and appropriate based on today's science in consistently tackling climate change at farm level
- Carbon emissions for red meat are often quoted using global averages, whereas the predominant farming systems in the UK cannot be compared to other global systems, with global averages being higher than that of the UK. We need to report at the tier 3 or local level to incentivise improvements
- A total of 72% of agricultural land in the UK is grassland, with a high proportion of grassland being unsuitable to grow anything else
- Ruminant livestock systems are capable of turning grassland, including marginal land, into nutritious protein
- Grazing ruminants have helped shape the natural landscape of the UK over centuries, delivering ecosystems services, such as managing and enhancing habitat, alongside producing food
- UK farms have some of the highest animal health and welfare standards in the world and we cannot put that at risk by chasing after a particular environmental goal
- UK livestock systems demonstrate circularity, enabling the careful use of by-products and cycling of nutrients to minimise waste and optimise output
- UK livestock agriculture has an important role to play in providing nutritious, sustainable food to a growing global population in addition to domestic consumers, with the UK being well placed to serve the increase in global demand for livestock products because of its environmental credentials
- The GHG National Inventory and CCC reports tend to look at country emissions with a drive to reduce them. We need to be mindful of the role the UK plays in the global context. We could reduce reported emissions by producing less, but if that leads to increased imports from less environmentally conscious countries, the global impact is negative
- The combination of circular farming practises, carbon storage and sequestration, along with the broader ecosystems services provided by farms, suggests that a sustainable planet is achievable without necessarily requiring a reduction in meat and dairy consumption to ensure adequate access to nutritious food

1. Introduction – Food systems and the role of sustainability on nutrition

Summary points

- Growing concerns about climate change, malnutrition, non-communicable diseases and food insecurity have fuelled the push for healthy and sustainable diets, making the environmental, health and ethical impacts of red meat highly debated
- Resilient food systems are crucial for promoting healthy and sustainable diets, encompassing food production, processing, distribution and waste management. This approach aims to achieve food security and adequate nutrition for all, while balancing economic, social and environmental sustainability
- Climate change poses significant challenges for food systems, impacting water resources, soil health and land use, and requires adaptive and resilient agricultural practices. The Food and Agriculture Organization's (FAO's) Achieving SDG 2 without breaching the 1.5°C threshold: A Global Roadmap 2023 advocates for global action to transform food systems, reduce greenhouse gas emissions, enhance biodiversity and promote sustainable agriculture. It emphasises healthy diets, education, policy interventions and access to nutritious foods to ensure global food security and wellbeing amid climate change
- A sustainable healthy diet promotes individual health and wellbeing while being environmentally sustainable. It should be low impact, accessible, affordable, safe, equitable and culturally acceptable. In the UK, the Eatwell Guide provides dietary recommendations, emphasising a balanced diet with a variety of plant-based foods and moderate animal-sourced foods, advising limits of red and processed meat to 70 g per day or 500 g per week due to cancer risks. However, fewer than 1% of the UK population follows these guidelines, though wider adherence could enhance public health and significantly reduce greenhouse gas emissions
- Red meat offers high-quality protein and essential nutrients like iron, zinc and vitamin B12, vital during critical life stages such as pregnancy and lactation, early childhood and older age. When consumed in moderation and paired with plant-rich foods, it contributes to a balanced diet. However, excessive intake of processed meats is linked to a higher risk of developing cancer, cardiovascular disease and type 2 diabetes
- Transitioning to plant-rich diets in high-income countries benefits both health and the environment. The UK's Climate Change Committee recommends a 20% reduction in red meat consumption by 2030 to meet climate goals. Research shows that following these guidelines can help achieve climate mitigation targets and address public health needs but cautions against blanket reductions due to potential micronutrient deficiencies in vulnerable groups. Aligning consumption with national dietary guidelines can enhance health outcomes and environmental sustainability

- Human development has pushed the planet beyond its environmental limits, as shown by the concept of planetary boundaries. While the energy sector is the largest contributor to greenhouse gas emissions, agriculture – especially livestock production – also has significant impacts, accounting for approximately 18.4% of global emissions. Despite the focus on livestock's contribution to emissions, it is only a fraction compared with sectors such as transport and energy. In the UK, livestock contributes 7% to national emissions, transport 28% and energy 22%, and farmers are already taking positive actions to support net-zero goals
- Achieving the UK's net zero target by 2050 requires significant advances in agricultural practices. Net zero means balancing total greenhouse gas emissions with those removed from the atmosphere. This involves enhancing carbon sequestration through reforestation and soil management, reducing emissions with renewable energy and improving energy efficiency. Farmers are adopting strategies to enhance animal health, feed efficiency and sustainability. Accurate measurement and baseline analysis of environmental impacts are essential for effectively managing emissions, ensuring food security and providing high-quality nutritious food
- Environmental and climate health challenges are multifaceted, encompassing agriculture, animal welfare, food production, biodiversity and social health. Addressing these issues requires a nuanced understanding of British red meat's role in a balanced diet, acknowledging its health and sustainability contributions when consumed in moderation

Introduction

In light of escalating concerns regarding climate change's destabilising impact on global ecosystems,[1] increasing prevalence of malnutrition, the burden on non-communicable disease[2] and the persistent challenge of food insecurity,[3] there is an increasing awareness of the importance of promoting and adhering to healthy and sustainable diets. Red meat's role within this context has sparked contentious debates relating to its perceived environmental, health and ethical impacts.[4,5]

This report provides a comprehensive, evidence-based analysis of red meat's multifaceted role in the UK diet, focusing on health and sustainability. It presents an overview of red meat's nutritional profile, its contributions to dietary intake and associations with health outcomes and disease risk. The report also explores the broader food system implications of red meat production, including environmental impacts and advances in sustainable practices by British farmers.

Food systems and the role of sustainability and nutrition

At the core of promoting healthy and sustainable diets is the resilience of food systems, which includes food production, processing, distribution, consumption, waste management, agriculture, horticulture, forest and fisheries.[6,7] The overarching objective of these systems is to ensure food security and adequate nutrition for all, while considering economic, social and environmental factors.[6,8]

Climate change poses significant challenges to the food system, particularly for farmers as they are heavily reliant on predictable weather patterns and sufficient growing seasons.[3,9] Issues such as water quality and accessibility, soil health and land use can put further strain on food production. As a result, there is an urgent need for adaptable, intervention-focused and resilient food systems that can withstand environmental challenges and ensure sustainability for future generations.[10,11]

The Food and Agriculture Organization of the United Nations' (FAO) publication, Achieving SDG 2 without breaching the 1.5°C threshold: A Global Roadmap, provides a comprehensive strategy to tackle hunger and climate change.[12] It calls for urgent global action to transform food systems, reduce greenhouse gas (GHG) emissions and improve biodiversity conservation. Emphasising a holistic approach, it integrates sustainable agriculture, food security measures and adaptation strategies. By aligning efforts across sectors and engaging stakeholders, the roadmap aims to effectively address the complex challenges of hunger, climate change and sustainable development.

Additionally, it underscores the importance of promoting healthy diets through education, policy interventions and the production and consumption of nutritious foods. Through these efforts, the FAO aims to ensure food security, nutrition and wellbeing, while mitigating the impacts of climate change.

What is a healthy, more sustainable diet?

According to the FAO and the World Health Organization (WHO), sustainable healthy diets are dietary patterns that promote individual health and wellbeing, minimise environmental impact, are accessible, affordable, safe and equitable, and are culturally acceptable.[9] The longer definition is provided in box 1.

Box 1. FAO/WHO sustainable healthy diets definition

Sustainable healthy diets aim to achieve optimal growth and development of all individuals and support functioning and physical, mental and social wellbeing at all life stages for present and future generations; contribute to preventing all forms of malnutrition (i.e. undernutrition, micronutrient deficiency, overweight and obesity); reduce the risk of diet-related NCDs; and support the preservation of biodiversity and planetary health. Sustainable healthy diets must combine all the dimensions of sustainability to avoid unintended consequences. (Page 9 of FAO/WHO, 2019)[13]

In the UK, adhering to the Government's dietary guidelines, as illustrated in the Eatwell Guide (Figure 1), is crucial.[14] This guide advocates for a balanced diet rich in diverse healthy plant-based foods, including fruits, vegetables, legumes, whole grains, nuts and seeds, while permitting inclusion of animal-sourced foods, such as meat, fish, eggs and dairy products.

The Eatwell Guide specifically recommends limiting red and processed meat consumption to 70 g (cooked weight) or less per day, or approximately 500 g per week (600–700 g raw weight). People consuming over 90 g (cooked weight) of red and processed meat per day are advised to reduce their intake to 70 g or less to mitigate the increased risk of colon cancer associated with higher consumption levels.[15]

The Eatwell Guide is based on foods familiar to the UK public and may be more culturally acceptable for the majority of people than diets that exclude all animal-based foods.[14] Not getting the right balance of foods in the diet may result in a lower intake of key nutrients and negatively impact health.[16–18]

It is important to note less than 1% of the UK population currently follows the Eatwell's dietary recommendations.[19] If these guidelines and dietary patterns were adopted by everyone in the UK, diet-related disease could be significantly reduced and the overall health of the population improved.[20] Greenhouse gas (GHG) emissions would also be reduced by a third, suggesting that aligning our diets to these guidelines benefits both individual health and the environment.[21]

Figure 1. The Eatwell Guide – The UK government's healthy eating recommendations

Source: (PHE,2018)[14]
https://assets.publishing.service.gov.uk/media/5bbb790de5274a22415d7fee/Eatwell_guide_colour_edition.pdf

The Eatwell Guide illustrates a balanced diet, including moderate amounts of red meat alongside various plant-based foods.

The role of red meat – Finding a balance

Red meat is nutritionally dense, providing high-quality protein and a variety of highly bioavailable micronutrients, including iron, zinc, vitamin B12, vitamin D and selenium,[22] which are essential for human health.[3] This bioavailability supports efficient absorption, particularly important during key life stages such as pregnancy and the first 1,000 days from conception to early childhood.[23] Additionally, when paired with plant-sourced foods rich in fibre and other nutrients, red meat can enhance a meal's nutritional profile, contributing to a nutritionally adequate and well-balanced dietary pattern.

It is, however, imperative to acknowledge that excessive consumption of red meat, particularly processed meat, has been associated with an increased risk of non-communicable diseases (NCDs), including cancer, cardiovascular disease and type 2 diabetes,[4] as covered in section 4, page 105. Striking a balance is crucial as there is no one-size-fits-all approach. For population groups with high red meat intake, particularly processed varieties, reducing consumption can significantly benefit both human health and the planet.[17] Conversely, populations at risk of malnutrition may benefit from increased red meat consumption.[23]

The UK's Climate Change Committee (CCC) has set targets to reduce red meat consumption in efforts to mitigate climate change.[24] One key target is a 20% reduction in total meat consumption (red and white meat) by 2030. This reduction is seen as a crucial step towards achieving climate goals and promoting more sustainable dietary patterns.

Recent research conducted by the University of Edinburgh and commissioned by Food Standards Scotland (FSS) identified that the existing dietary recommendations outlined in the Eatwell Guide could help Scotland meet the mitigation goals for climate change set by the CCC.[17] However, this study highlights the complexity of the issue, emphasising that a blanket reduction in meat consumption may worsen micronutrient intake, particularly among population groups that already exhibit poor dietary habits.

Aligning current consumption patterns in high-income countries with national food-based dietary guidelines (FBDGs), particularly by increasing consumption of plant-derived over animal-derived foods, is conducive to improving both environmental and population health.[19,25] The transition to a plant-rich diet that features moderate intake of animal-derived products aligns with the dietary recommendations put forward by both the FAO and WHO for a healthy and sustainable diet.[13]

Sustainable farming practices – Understanding net zero

Human development on Earth, driven by technological advancements, economic growth and the escalating demand for food and resources, has come at a significant environmental cost. This growth has pushed the planet beyond its capacity to sustain these activities without severe consequences.[26] This concept is encapsulated in the planetary boundaries' framework, which defines scientific thresholds through which humanity can safely operate. Crossing these thresholds could lead to irreversible environmental damage to key planetary boundaries, including climate change, biodiversity loss, land-use change, freshwater use and biochemical cycles such as nitrogen and phosphorus.[27]

Recent assessment of the planetary boundaries framework identified that six of the nine boundaries, including climate change, have now been crossed, signalling that human activities are pushing Earth's systems towards critical thresholds.[26] The vast majority of global GHG emissions (73.2%) originate from the energy sector; however, agriculture – particularly production of animal products such as red meat – also plays a significant role in influencing these boundaries. Agriculture, forestry and land use together contribute approximately 18.4% of global GHG emissions, making it a critical sector in discussions on sustainable development.[28]

Livestock meat production is often cited as a major contributor to climate change, primarily due to high GHG emissions from animals, feed production and fossil fuel use. However, this view neglects the potential for farms to offset these emissions. For instance, UK government figures show that livestock accounts for 7% of national GHG emissions – significantly lower than emissions from transport (28%) and energy (electricity and fuel – 22%)[29–31] (see Figure 2). These figures overlook the positive actions farmers take to support net-zero goals and food security. Net zero involves reducing carbon emissions to a minimal level that can be naturally absorbed and stored, resulting in zero net emissions in the atmosphere.[32] A more comprehensive approach involves assessing the net carbon position of farms, factoring in both emissions and carbon sequestration from practices such as tree planting, soil enhancement and the adoption of renewable energy use. Methods such as rotational grazing and integrating trees can enhance carbon storage on farms.

While the UK's legislation to achieve net zero by 2050 cements the need to dramatically reduce global GHG emissions, environmental sustainability encompasses more than just emissions reduction. The UK government's Department of Energy Security and Net Zero (DESNZ)[33] highlights that shifting towards net zero in agriculture requires improving productivity, reducing emissions and enhancing farmland's ecological value. By optimising animal health, feed efficiency, soil health, enhancing biodiversity and producing green energy from wind and solar, farmers are working to minimise their environmental footprint while continuing to provide high-quality protein for the global population.

Figure 2. Carbon dioxide equivalent emissions of seven greenhouse gases from within UK borders

Source: BEIS (2024);[30] NAEI (2024)[31]

In summary, improving environmental and climate health is a multi-dimensional challenge that requires addressing the interconnected issues of farming, animal welfare, food production, biodiversity, climate change and societal health through multiple systems. In parallel it is essential to consider factors linked to a healthier and sustainable diet, including nutrition, health benefits and acceptability, while ensuring enough safe food for the growing global population.

The narrative surrounding British red meat should recognise its potential contribution to both health and sustainability when consumed in moderation as part of a healthy, balanced diet. By fostering a nuanced understanding of livestock's role, we can create a food system that delivers nutritional value, supports livelihoods, respects cultural significance and mitigates environmental impacts.

References

1. Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M.G., Field, C.B. and Knowlton, N. (2020). Climate change and ecosystems: threats, opportunities and solutions. Philosophical Transactions of the Royal Society. Biological Sciences 375: 2019010
2. Fanzo, J.C. and Downs, S.M. (2021). Climate change and nutrition-associated diseases. Nature Reviews Disease Primers 7: 90.
3. Farooq, M.S., Uzair, M., Raza, A., Habib, M., Xu, Y., Yousuf, M., Yang, S.H. and Khan, M.R. (2022) Uncovering the Research Gaps to Alleviate the Negative Impacts of Climate Change on Food Security: A Review. Frontiers. Plant Science. 13:927535.
4. World Health Organization (WHO). (2023). Red and processed meat in the context of health and the environment: many shades of red and green. Information brief. Available at: **https://www.who.int/publications/i/item/9789240074828** (Accessed 23 August 2024).
5. Leroy, F., Heinrich, F., Lee, M.R.F. et al. (2023). Meat matters: making the case for a valuable food in a hostile environment. Italian Journal of Animal Science 22(1): 885–897.
6. Food and Agriculture Organization of the United Nations (FAO). (2018a). Sustainable food systems: concept and framework. Available at: Sustainable food systems: Concept and framework (**fao.org**) (Accessed 23 August 2024).
7. Willet, W., Rockström, J., Loken, B. et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170): 447–-492.
8. Food and Agriculture Organization of the United Nations (FAO). (2017). The future of food and agriculture: trends and challenges. Available at: **https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/472484/** (Accessed 23 August 2024).

9. Food and Agriculture Organization of the United Nations (FAO). (2019). FAO's work on climate change: United Nations Climate Change Conference 2019. Available at: **https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1255952/** (Accessed 23 August 2024).
10. Food and Agriculture Organization of the United Nations (FAO). (2018b). Transforming food and agriculture to achieve the SDGs: 20 interconnected actions to guide decision-makers. Available at: **https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1140709/** (Accessed 23 August 2024).
11. The Intergovernmental Panel on Climate Change (IPCC). (2019). Special report: climate change and land. Available at: **https://www.ipcc.ch/srccl/** (Accessed 23 August 2024).
12. Food and Agriculture Organization of the United Nations (FAO). (2023). Achieving SDG 2 without breaching the 1.5˚ C threshold: a global roadmap. Available at: **https://openknowledge.fao.org/handle/20.500.14283/cc9113en** (Accessed 23 August 2024).
13. Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). (2019). Sustainable healthy diets: guiding principles. Available at: **https://openknowledge.fao.org/handle/20.500.14283/ca6640en** (Accessed 23 August 2024).
14. Public Health England. (2018). A quick guide to the government's healthy eating recommendations. Available at: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/742746/A_quick_guide_to_govt_healthy_eating_update.pdf** (Accessed 8 July 2023).
15. SACN (Scientific Advisory Committee on Nutrition). (2010). Iron and health. Available at: **https://assets.publishing.service.gov.uk/media/5a7df3dd40f0b62305b7fd53/SACN_Iron_and_Health_Report.pdf** (Accessed 26 October 2023).
16. World Health Organization (WHO). (2020). Healthy diet: key facts. Available at: **https://www.who.int/news-room/fact-sheets/detail/healthy-diet** (Accessed 23 August 2024).
17. Food Standards Scotland (FSS). (2024). Modelling the impact of reductions in meat and dairy consumption on nutrient intakes and disease risk. Available at: **https://www.foodstandards.gov.scot/downloads/Summary_briefing_-_Modelling_the_impact_of_reductions_in_meat_and_dairy_.pdf** (Accessed 13 March 2024)
18. Leonard, U.M., Leydon, C.L., Arranz, E. et al. (2024). Impact of consuming an environmentally protective diet on micronutrients: a systematic literature review. American Journal of Clinical Nutrition, 119(4): 927–948..
19. Steenson, S., Buttriss, J.L. (2021). Healthier and more sustainable diets: What changes are needed in high-income countries? Nutrition Bulletin, 46(3): 279–309.
20. Scarborough, P., Kaur, A., Cobiac, L. et al. (2016). Eatwell Guide: modelling the dietary and cost implications of incorporating new sugar and fibre guidelines. BMJ Open, 6(12): e013182.
21. Scheelbeek, P., Green, R., Papier, K. et al. (2020). Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: analyses of multiple UK studies. BMJ Open, 10(8): e037554.
22. Public Health England (PHE). (2021). Composition of foods integrated dataset (CoFID). McCance and Widdowson's composition of foods integrated dataset. Available at: **https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid** (Accessed 20 July 2024).
23. Beal, T., Gardner, C.D., Herrero, M. et al. (2023). Friend or foe? The role of animal-source foods in healthy and environmentally sustainable diets. The Journal of Nutrition 153(2): 409–425.
24. Climate Change Committee (CCC). (2020). The sixth carbon budget – the UK's path to net zero. December, 2020. London, Committee on Climate Change.
25. Springmann, M., Spajic, L., Clark, M.A. et al. (2020). The healthiness and sustainability of national and global food based dietary guidelines: modelling study. British Medical Journal 370: m2322.
26. Richardson, K., Steffen, W., Lucht, W. et al. (2023). Earth beyond six of nine planetary boundaries. Science Advances 9(37): eadh2458.
27. Steffen, W., Richardson, K., Rockström, J. et al. (2015). Planetary boundaries: Guiding human development on a changing planet. Science 347(6223): 1259855.
28. Our World in Data (2020). Sector by sector: where do global greenhouse gas emissions come from? Available at: **https://ourworldindata.org/ghg-emissions-by-sector** (Accessed 23 August 2024).
29. Magowan, E., Buckingham, S., McAuliffe, G., Rees, R and Lee, M.R.F. (2020) Net zero carbon and UK livestock report. Centre for Innovation Excellence in Livestock (CIEL).

30. UK Government Department of Energy, Security and Net Zero (DESNZ). (2024). Final UK greenhouse gas emissions national statistics: 1990 to 2022. Available at: https://www.gov.uk/government/organisations/department-for-energy-security-and-net-zero/about/statistics
31. National Atmospheric Emissions Inventory (NAEI). (2024). Greenhouse gas inventories for England, Scotland, Wales and Northern Ireland: 1990–2022. Available at: **https://naei.energysecurity.gov.uk/sites/default/files/2024-10/ukghgi-90-22_Main_issue1.pdf** (Accessed 6 December 2024).
32. United Nations (UN). (2023). Climate action. Available at: https://www.un.org/en/climatechange/net-zero-coalition (Accessed 12 September 2024).
33. UK Government Department of Energy, Security and Net Zero (DESNZ). (2023). Guidance: UK net zero research and innovation framework, updated March 2023. Available at: **https://www.gov.uk/government/publications/net-zero-research-and-innovation-framework/uk-net-zero-research-and-innovation-framework#chapter-4-6** (Accessed 12 September 2024).

2. Red meat – UK dietary recommendations, guidance, consumption and purchasing trends

Summary points:

- For more than 2.6 million years, meat consumption has provided vital nutrients, including high-quality protein, essential fatty acids and important vitamins and minerals. Despite its nutritional benefits, red meat often faces criticism regarding health and sustainability
- Red meat includes beef, lamb and pork, while processed meat refers to meat preserved by methods such as salting, smoking and marinating, including ham, bacon and sausages. These definitions are often inconsistently applied in epidemiological studies, with red and processed meats frequently grouped together in dietary guidelines, national surveys and research
- In 2010, the UK Scientific Committee on Nutrition (SACN) recommended that adults consuming over 90 g of red and processed meat per day reduce their intake to no more than 70 g per day (cooked weight) to lower their colorectal cancer risk. This recommendation aligned with findings from the World Cancer Research Fund (WCRF) and the American Institute of Cancer Research (AICR), who identified high processed meat intake as a convincing cause and red meat as a probable cause of colorectal cancer. WCRF suggests that red meat can be part of a balanced diet in moderation, recommending up to three portions per week (350–500 g cooked weight) to balance its nutritional health benefits against potential colorectal cancer risk
- The SACN recommendation informed the UK Government's Eatwell Guide, which encourages consumption of more plant-based proteins, sustainably sourced fish and eggs, while limiting red and processed meat to no more than 70 g/day (500 g/week). Those consuming over 90 g per day should try to reduce intake to 70 g or less
- Historically, food-based dietary guidelines (FBDGs) around the globe have rarely addressed red and processed meat consumption, with few countries recommending limits. Recently, there has been an increasing trend to develop FBDGs that consider health risks such as colon cancer, as well as environmental sustainability. Nordic countries, Spain, Germany and Austria emphasise plant-based diets and reduced red and processed meat intake to support both health and sustainability. However, to date, no United Nations (UN) agency has established specific targets for red and processed meat consumption
- When developing FBDGs, caution is advised to avoid unintended nutritional consequences, such as reduced meat intake negatively affecting population health. Recommendations must consider nutritional suitability, the impact on vulnerable groups and factors such as local needs, affordability and environmental impact
- The planetary health diet by the EAT– Lancet Commission recommends over a 50% reduction in global red meat consumption by 2050. However, researchers point out its limitations, including

reliance on US-centric data with limited food groups and its failure to provide essential micronutrients, such as iron, vitamin B12, calcium and zinc, which is particularly concerning for women of reproductive age who have higher iron needs

- In response to the Climate Change Committee (CCC) targets to reduce meat consumption by 20% by 2030, Food Standards Scotland (FSS) researched the public health impact of further cuts in red and processed meat consumption. They found that many within the Scottish population do not meet Scottish Dietary Goals (SDGs) for red and processed meat and focused their modelling on high consumers. If higher consumers of red meat reduced their intake to the recommended 70 g per day, it would yield health benefits and a 16% decrease in total meat consumption, contributing to the CCC target
- Research highlights the risks of further reducing meat consumption in the UK, with FSS warning that reductions beyond current guidelines could exacerbate micronutrient deficiencies in an already vulnerable population. The historical analysis of SACN found that lowering the intake of red meat to 70 g/day increased the proportion of men with zinc intake below the LRNI by 5%, increasing the risk of deficiency. Additionally, each 10 g reduction in consumption (down to 50 g) led to a decrease in iron intake in women, further increasing the proportion of the population with an intake below the LRNI for iron and zinc in both men and women and, as a consequence, increasing the risk of deficiencies. Furthermore, this data was gathered before reductions in red and processed meat consumption became so apparent, suggesting that more UK research is needed
- The National Diet and Nutrition Survey (NDNS) report for years 9–11 (2016/17–2018/19) shows that the average red and processed meat consumption in the UK is within the recommended limit of 70 g per day. It was 56 g/day for those aged 19–64. Males aged 19–64 had the highest intake at 69 g/day, while for females, those aged 11–18 had the highest intake, with an average of 46 g/day. Overall meat consumption has steadily declined across all age groups since 2008
- The NDNS data combines meat abstainers and consumers, affecting average figures, and does not separate red from processed meat consumption in its main findings, despite having detailed participant data. To address this, a secondary analysis focused on meat consumers only, revealing an average intake of 63 g per day for adults (aged 19+). Men consume more red and processed meat than women, especially at higher levels (>90 g/day and >70 g/day), with most women (69–81%) consuming less than 70 g/day
- Most adults (64%) meet the recommendation of consuming no more than 70g of red and processed meat daily, with higher compliance among women (73%) than men (53%). Consumption varies widely, particularly among adult males aged 19–64. Among those exceeding the 70 g/day threshold, 54% are men aged 19–39 and 31% are women in the same age group. Younger adults generally consume more red and processed meat than older adults. For instance, men aged 19–39 average 86 g/ day, ranging from 13 g to 196 g per day. There is also a segment of the population that does not consume red and processed meat at all, with higher rates of non-consumption among middle-aged women
- Household purchasing data from 1980 to 2023 shows a steady decline in red meat purchases, with chicken now more popular. Since 2012, primary red meat purchases have dropped by 26%. The decline is driven by factors such as price, health concerns, animal welfare and environmental concerns, the cost-of-living crisis and the impact of COVID-19. Consumers increasingly choose perceived healthier options, such as chicken and fish, while those being more price sensitive are

often opting for affordable processed meats. Currently, sales of processed and other meats (e.g. pies, sausage rolls, burgers, ready meals) have surpassed primary red meat and poultry, averaging over double the sales. Clear sales distinctions exist between pies and ready meals compared with the various red meats and poultry.

- A clearer distinction between red and processed meat is crucial in dietary guidelines and research due to their differing nutritional profiles and associated health risks. Currently, conflating the two complicates public messaging and policy making. Improved research protocols are needed for accurate assessments of health risks and environmental concerns. This distinction would enhance organisational messaging and enable consumers to make more informed food choices

Introduction

Meat consumption has been crucial to human evolution for over 2.6 million years.[1] Its inclusion in the diet has significantly influenced brain development and the trajectory of early humans as active, social primates.[2] Today, red meat remains important for its provision of essential nutrients, including high-quality protein, essential fatty acids and vital vitamins and minerals. Maintaining good health is essential, but navigating nutrition and health communications can be complex. Media often presents conflicting messages, focusing on individual nutrients or foods rather than overall dietary patterns, demonising or glorifying specific foods or nutrients. Incidentally, red meat receives unwarranted criticism as a result of oversimplified discussions on its nutritional impact on health and a negative perception of agricultural practices and sustainability.[3]

It is crucial that the environmental impact of livestock products is assessed using balanced metrics. Beyond red meat's nutritional benefits, it is important that the societal contributions of well-managed farms, such as biodiversity, soil health, land stewardship and rural community support, are also acknowledged. Environmental sustainability is not just about reducing greenhouse gas (GHG) emissions alone; it also requires efforts to use resources more efficiently, minimise waste, enhance biodiversity and improve carbon sequestration.[4]

Indeed, debates on the environmental sustainability of livestock farming have become so unbalanced, over 1,200 scientists and academics across the globe have become signatories to the Dublin Declaration.[5] Collectively, under the declaration, the signatories will use the highest scientific rigour and standards to provide reliable evidence on the nutrition and health benefits of red meat, its environmental sustainability and economic and sociocultural values.[6] Ongoing scientific debate and critical inquiry is emphasised, along with focused development of balanced and inclusive strategies regarding the impact of red meat on population health and environmental food system transformation.

In parallel to the Dublin Declaration,[5] this report will provide scientific evidence behind the important role red meat can play in the UK as part of a healthy, balanced and sustainable diet.

Definitions of red and processed meat

This report's definitions of red and processed meat are based on the common definitions used by epidemiological studies examining the impact of red meat consumption on health across Europe and the UK (Table 1).[7,8,9] Specific focus will be on beef, lamb and pork, and, where possible, separating processed meat, as the method of production, ingredients used and nutrient profile differ significantly.

Table 1. Definitions

Type of meat	Definition
Red meat	Includes beef, pork and lamb (including fresh, minced and frozen)
Processed meat	Includes meat that has been preserved by methods other than freezing, such as salting, smoking, marinating, air-drying or heating – for example, ham, bacon, sausages, hamburgers, salami, corned beef and tinned meat

Source: Linseisen et al. (2002)[9]

Current dietary recommendations for red meat consumption within the UK

In 1998, the COMA report, Nutritional aspects of the development of cancer,[10] identified a potential link between red and processed meat consumption and colorectal cancer, advising "higher consumers should consider a reduction". Later, in 2007, a joint World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) panel found excessive intake of red and processed meat consumption increases colorectal cancer risk,[11] with strong evidence that processed meat was the cause. WCRF and AICR therefore recommended moderate consumption of beef, pork and lamb and minimal processed red meat consumption.[12,13] Since red meat is an important source of iron in the UK diet, the Scientific Committee on Nutrition (SACN) established dietary guidelines in its 2010 advisory on iron and health,[14] recommending average red and processed meat intake should not exceed 70 g/day. It also specifically highlighted that anyone eating more than 90 g of red or processed meat per day (considered to be a high consumer) should try to reduce meat consumption so that the weekly average remained below 70 g/day. These guidelines were subsequently accepted by Public Health England and form the basis of the current UK dietary recommendations.[15]

Establishment of the SACN red meat dietary guidelines was based on a model to assess the impact of decreased red meat intake on nutritional health, particularly focusing on the contribution of red meat to iron, zinc and vitamin D status. Reducing red meat intake to less than 70 g/day significantly increased the risk of deficiency, providing strong evidence that red meat plays an important role in meeting reference nutrient intakes for key micronutrients. In summary, SACN identified that average meat consumption was 88 g/day for men and 52 g a day for women. Furthermore, red meat contributed more to zinc (32% for men, 27% for women) than iron intake (12% for men, 9% for women). Reducing red meat to 100, 90 or 80 g/day had minimal impact on the number of people below the lowest reference nutrient intake (LRNI) for iron or zinc. However, limiting red meat consumption to 70 g/day slightly increased the percentage of men below the LRNI for zinc, from 3.7% to over 5%. Red meat also provides about one-sixth of dietary vitamin D, with reductions to 100, 90, 80 or 70 g/day having little effect on vitamin D intake for either gender.[14] It is therefore crucial to consider the potential nutritional implications if red meat consumption recommendations were to reduce further, especially given the recent reductions in red meat consumption patterns since the original SACN review. It highlights very clearly that further research is required to understand the impact of any further decrease in red meat consumption on nutrient intakes and public health.

For instance, the Eatwell Guide, the UK Government's food-based dietary guidelines, currently recommends reducing red and processed meat consumption while increasing beans, pulses and eating two portions of sustainably sourced fish and eggs.[15] Revised from The Eatwell Plate in 2016, the guide emphasises sustainable food choices and that adhering to these recommendations could improve both public health and environmental outcomes.[16]

Most public health and other non-governmental organisations recommend limiting processed meat intake.[12,13,17] WCRF (2023)[12] clarifies that this does not mean eliminating meat completely as it provides essential nutrients, such as protein, iron, zinc and vitamin B12. WCRF suggests limiting red meat to no more than three portions per week (approximately 350–500 g cooked) and minimising processed meat consumption. This approach balances the nutritional benefits of red meat with the associated risk of colorectal cancer and other non-communicable diseases. Table 2 provides some examples of what this might look like in practical terms when preparing meals across the week.

Table 2. Examples of incorporating red meat portions into balanced meals according to government recommendations

Red meat	Cooked weight (g)	Raw weight (g)	Meal inspiration
Lean beef mince	100	125	Use in Bolognese sauce with carrots celery and lentils, and use wholewheat spaghetti
Lean beef rump steak	130	125	Cut in strips for fajitas with plenty of onions, peppers and mushrooms, with wholemeal wraps
1 pork sausage (grilled)	45	57	For a weekend brunch with poached eggs, tomatoes, mushrooms and wholegrain toast
Lean diced lamb	100	140	In a lamb kebab with wholemeal pitta, salad and herby yogurt dressing
Pork chop (edible portion)	75*	110	Use in a tray bake, with butter beans, roasted vegetables and potatoes (keep the skins on)
Total for the week	**450**	**557**	

Note: These suggestions are not a definitive approach, they just show a few ways in which red meat can be included in some balanced dishes within the current UK recommendations.

Source: British Nutrition Foundation (2021)[18]; *Food Standards Agency (2002)[19]

Global food-based dietary guidelines

The WHO report, Red and processed meat in the context of health and environment, examines the historical shift towards balanced dietary guidance since the early 1990s, leading to recommended limits on red and processed meat.[20] Since 2003, a joint WHO/FAO expert consultation report on diet, nutrition and the prevention of chronic disease concluded that diets high in red meat are associated with certain cancers, leading to the recommendation towards more moderate consumption.[21] However, no United Nations (UN) agency has set specific targets for red meat production or consumption. Instead, the FAO/WHO guidelines recommend a healthy sustainable diet, including “moderate amounts of eggs, dairy, poultry and fish; and small amounts of red meat” (FAO/WHO, 2019; p11).[22]

Surprisingly, across the globe, few food-based dietary guidelines (FBDGs) address red and processed meat consumption. A 2019 study of FBDGs from 90 different countries found that only 23% recommended limiting red or processed meat, with just 11% specifically mentioning them. Only four countries set upper consumption limits: Finland and Sweden (500 g/week), Qatar (<500 g/week) and Greece (one serving per week).[23] Since then, France and Belgium have also set limits.[20] New FBDGs from the Nordics,[24] Spain,[25] Germany[26] and Austria[27] emphasise reducing red and processed meat intake and promoting plant-based diets and sustainability via consumption of local and seasonal produce.

The Nordic Nutrition Recommendations (2023) emphasise the importance of food for health and the environment, advocating for plant-based eating, with limited red meat and poultry intake (less than 350 g of cooked red meat) and minimal processed meat.[24] Spain suggests consuming 0–3 servings of meat per week, focusing on white meats such as poultry and rabbit while minimising processed meats. Each serving is 100–125 g – equivalent to one medium steak, a quarter of a chicken or a quarter of a rabbit.[25] Germany recommends under 300 g per week, highlighting that plant-based foods should form the basis of a healthy diet, with animal products supplemented in smaller quantities – with a “less is more” message.[26] Austria suggests one portion of meat and one of fish weekly, with an optional additional portion of meat or fish.[26] However, criticisms of these recommendations include concerns about nutritional adequacy, biodiversity loss from reduced livestock, limited carbon sequestration from grazing systems, methane from ruminants being part of the natural carbon cycle, lack of comprehensive environmental data and the potential impact on food security.[28]

In 2018, the global average intake per person was 51 g/day of unprocessed meat and 17 g/day of processed meat, varying from 7 g/day in South Asia to 118 g/day in Central and Eastern Europe and Asia.[29] The Global Burden of Diseases (GBD) Risk Factors Study suggests the global average is about 500 g of red meat per week (≤75 g/day or ≤ four portions/week).[30]

It is important to clarify that FBDGs cater to each country’s specific needs, leading to different dietary recommendations based on current animal-based food intakes.[20] It is essential to assess nutritional intake, especially for vulnerable population groups, to avoid negative consequences from reduced red meat consumption. This includes considering dietary protein, essential fatty acids and micronutrient status, as highlighted by surveys such as the UK’s National Diet and Nutrition Survey (NDNS).

Following the UK Climate Change Committee’s (CCC) targets to reduce meat and dairy consumption,[31] Food Standards Scotland (FSS) commissioned a study to assess the implications of a 20% reduction in total meat consumption by 2030 (and 30% by 2050).[32] They focused on high consumers of red and processed meat (over 70 g/day), which represented 28% of adults, typically males aged 25–34, in deprived areas, averaging 117 g/day. Their modelling showed that if all Scottish adults adhered to the Scottish Dietary Goals (SDGs) of a maximum 70 g of red and processed red meat a day, it would result in a 16% reduction in total meat intake.[32]

Long-term health impacts from small reductions in average body mass index (BMI) could lead to fewer cases of cardiovascular disease and an estimated 10,000 fewer cases of type 2 diabetes over 10 years. As a consequence, FSS advises that we focus on achieving all the SDGs by supporting the more widespread adoption of UK FBDGs, as per the Eatwell Guide recommendations to address health and climate change concerns. However, FSS cautions that reducing red meat intake beyond current guidelines to 31–60 g per day may compromise micronutrient levels (iron, zinc, selenium and vitamin B12) in an already nutritionally vulnerable population.[32]

Nations reviewing dietary recommendations, especially those integrating sustainability considerations, must evaluate proposed models against current dietary habits, nutritional status and lifelong nutrition needs to avoid harming public health. The recent WHO Diet Impact Assessment Model[33] may help, provided its data is valid, unbiased, relevant and up to date and that the assessment context accounts for local demographics, cultural behaviours and environmental conditions in order to prevent unintended health consequences.

Recommendations made by expert and academic groups

The planetary health diet

From an environmental sustainability perspective, some researchers propose specific red meat consumption targets, such as the EAT–Lancet Commission. Through their planetary health diet, they advocate for over a 50% global reduction in red meat consumption by 2050, suggesting a limit of less than 98 g/week, while still meeting nutritional needs.[34]

Nutritional scientists, however, highlight limitations of the planetary health diet, noting its reliance on US-centric data and inclusion of limited food groups, which supplies essential micronutrients such as iron, vitamin B12, calcium and zinc inadequately, as a consequence of reduced consumption of animal-sourced foods, including red meat. They emphasise the need to reassess the planetary health diet to include more animal-sourced foods (specifically beef and pork) to prevent micronutrient deficiencies, especially iron for women of reproductive age.[35] Additionally, concerns about affordability arise, suggesting the diet may be out of reach for 1.58 billion people.[36] More studies on optimising diets to meet nutrient requirements with minimal environmental impact are required. Furthermore, as already discussed here and elsewhere in the report (page 11), modelling studies have demonstrated that adherence to the UK Eatwell Guide recommendations yields significant environmental and health benefits, including nutritional adequacy.[16,37]

This demonstrates that we already have a solution that balances health, affordability and sustainability.[38] The focus now should be on improving communications through a collaborative network of government, non-governmental organisations (NGOs), industry and healthcare representatives to deliver clear, consistent messages that align with the Eatwell Guide and address both planetary and public health needs, while remaining culturally relevant.

Red meat consumption and its nutritional contribution to UK diets

National Diet and Nutrition Survey (NDNS)

Data on current red meat intake and its nutritional contributions to UK diets is available from the National Diet and Nutrition Survey (NDNS) report for years 9–11 (2016/17–2018/19).[39] The NDNS is a continuous cross-sectional survey that collects detailed information on food consumption, nutrient intake and nutritional status of the UK population aged 1.5 years and older in private households. Conducted since 2008, it includes a representative sample of approximately 1,000 people annually, providing crucial evidence to identify nutritional issues and monitor progress towards public health nutrition goals.[40]

Comparison of red and processed meat intake with UK government recommendations

The NDNS report (years 9–11, 2016/17–2018/19) reveals that the mean consumption of red and processed meat across all age and sex groups is within the recommended limit of 70 g per day.[39] The highest average intake was 56 g/day for men and women aged 19–64 combined. In terms of gender males aged 19–64 and girls aged 11–18 reported the highest average intake at 69 g/day and 46 g/day, respectively, whereas younger children had the lowest overall intake (see Table 3).

Table 3. Average consumption of red and processed meat (g/day) (including non-consumers) by age (1.5 years and over) and gender (currently published available NDNS data)

	1.5–3 years	4–10 years	11–18 years	19–64 years	65+ years	65–74 years	75+ years
All	22	39	53	56	51	53	48
Male	-	38	60	69	63	66	58
Female	-	39	46	44	41	41	40

Source: NDNS (years 9–11, 2016/17–2018/19)[39]

Compared with the previous NDNS survey (2014–2016), the median consumption of red and processed meat decreased for men aged 19–64 (from 66 g to 58 g per day) and adults aged 65+ (from 55 g to 44 g). Notably, men aged 65–74 also saw a decrease, from 75 g to 58 g per day.[39] The data shows a clear trend of reduced red and processed meat consumption with age.

NDNS data since 2008 shows consistent reductions across all age groups; specifically, reductions of approximately 13 g per day for ages 11–18, 23 g for ages 19–64 and 19 g for those 65 years and older.[39]

While the reported average intake of red and processed meat aligns with government guidelines, context is important. The NDNS report includes individuals who abstain from meat consumption due to vegan, vegetarian or other dietary choices. Additionally, it does not analyse red and processed meat consumption separately, despite participants providing details on the specific types of meat. The report presents only combined intake data, indicating the need for further analysis to better understand red and processed meat consumption.

Secondary analysis of NDNS data, categorised by meat type and excluding meat abstainers

To address the need for greater scientific accuracy, the British Nutrition Foundation (BNF) conducted a secondary analysis using unpublished NDNS data (years 9–11, 2016/17–2018/19).[39] This analysis focused on red and processed meat consumption in the UK, categorising adults by those eating over 90 g/day, 70 g/day and under 70 g/day, by gender and age, as well as examining the nutrients provided by these meats in the diet.[41] The average consumption of red and processed meat was 63 g per day for adults aged 19+ (Table 4). Findings showed that males in all age groups (19+; 19–39; 40–64; 65+) report higher consumption of red and processed meat at >90 g/day and >70 g/day, respectively. In contrast, 69–81% of those consuming under 70 g/day are females aged 19–65+ (see Table 4).

Among adults aged 19 years and older (n=1,844), 64% meet the Government's recommendation to limit red and processed meat to no more than 70 g daily, equating to 53% of men and 73% of women. These statistics align with previous NDNS findings showing that the percentage of adults following the SACN guideline of limiting red and processed meat to 70 g a day increased from 47% in 2008–2009 to 66% in 2018–2019.[42] Average meat consumption decreased significantly from 103.7 g to 86.3 g per day, with reductions of 13.7 g in red meat and 7 g in processed meat.

Intake levels varied widely, from 0.03–312.96 g/day for all adults; 0.06–312.96 g/day for men; and 0.03–226.76 g/day for women. This large variation highlights the need for health-based messaging to target the higher-end meat consumers, particularly men aged 19–64, whose meat intake ranges from 2.5–301.31 g.

Table 4. Red and processed meat intakes in adult consumers (aged 19+): categorised by age and gender (average; % consumers; range; percentiles)

Red and processed meat intakes per day	Age (years)											
	19+ (n=1,844)			19–39 (n= 572)			40–64 (n= 820)			65+ (n=452)		
	All	M	F	All	M	F	All	M	F	All	M	F
Average (g)	63.1	77.6	52.4	68.1	85.8	56.2	64.5	78.7	53.8	54.7	66.9	45.4
>90 g (%)	23	33	15	27	39	19	24	33	16	16	26	8
70–89.99 g (%)	13	15	12	13	15	12	13	13	12	13	16	11
Total >70 g (%)	36	48	27	40	54	31	37	46	28	29	42	19
<69.99 g (%)	64	53	73	60	46	69	64	54	72	71	58	81
Range (g)	0.03–313	0.06–313	0.03–227	0.04–301	2.5–301	0.04–227	0.06–313	0.06–313	0.14–180	0.03–192	0.12–192	0.03–138
5th percentile (g)	8.9	12.2	7.6	8.6	12.7	7.4	9.0	12.9	7.5	8.3	10.3	7.5
95th percentile (g)	150.1	174.7	120.2	169.1	195.6	129.5	153.6	180.8	122.3	125.0	141.3	107.1

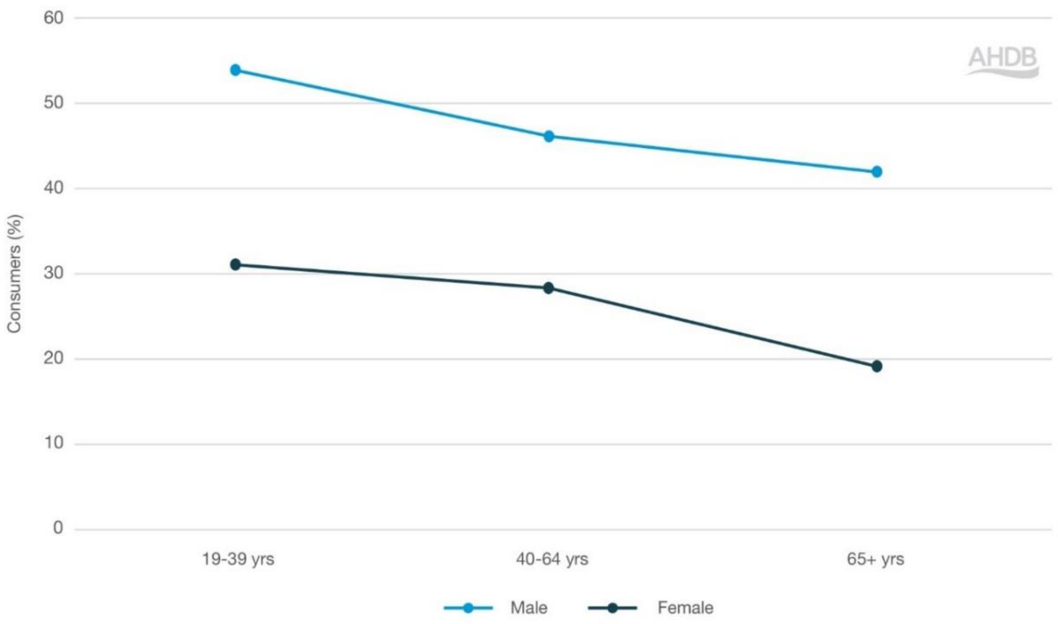
Key: M – male; F – female; n – number; g – gram; % – percentage of consumers

Note: Very small amounts of meat consumed may come from composite recipes used once over the four-day measurement period, leading to the small decimal place values seen within the ranges. The 5th and 95th percentile data reflects a range that covers 90% of the population.

Source: Secondary analysis of NDNS data (years 9–11, 2016/17–2018/19)[41]

Focusing on individuals that exceed the 70 g/day threshold for red and processed meat consumption, younger males are more likely to exceed the threshold, with 54% for those aged 19–39, compared with 46% aged 40–64 and 42% aged 65 and above. Although fewer females, surpass 70 g/day, younger women also show higher consumption rates, with 31% for those aged 19–39, compared with 28% aged 40–64 and 19% aged 65 and above, as illustrated in Figure 1. This highlights a clear pattern of higher red and processed meat intake among younger adults when compared with their older counterparts.

Figure 1. Gender differences in red and processed meat consumption over 70 g/day



Key: M – male; F – female

Source: Secondary analysis of NDNS data (years 9–11, 2016/17–2018/19)[41]

Non-consumer and meat consumer patterns

Further data analysis reveals 7–16% of adults aged 19–65+ do not consume any red and processed meat, with higher rates of non-consumption among women aged 40–64 (16%), and lower rates among men aged 65+ (7%). When making the distinction between intake of red and processed meat, average consumption was higher for all adults who consume red meat. Older adults had lower consumption levels of both red and processed meat, with figures at 36.82 g and 29.98 g, respectively (Table 5).

Table 5. Average red versus processed meat intake (g/day) in adult consumers (19+ years), including ranges

Intake g/day	Age (years)			
	19+ (n=1,844)	**19–39 (n= 572)**	**40–64 (n= 820)**	**65+ (n=452)**
Red meat	40.2	40.4	42.2	36.8
Range	0.01–249.9	0.07–232.8	0.01–249.9	0.03–142.9
Processed meat	36.0	40.2	36.3	30.0
Range	0.04–213.5	0.04–164.1	0.06–213.5	0.06–133.4

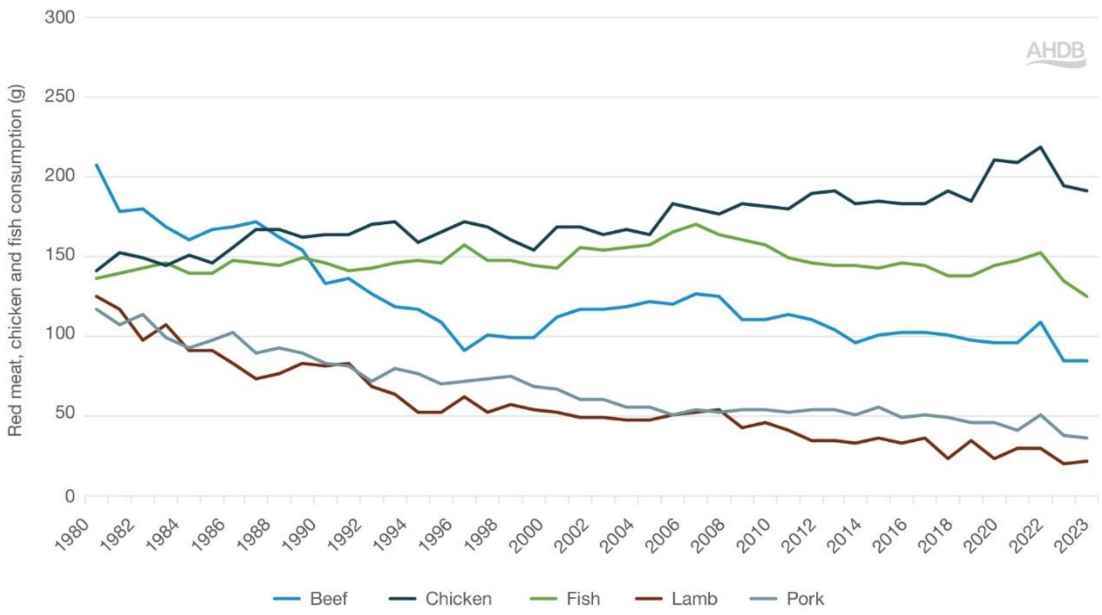
Source: Secondary analysis of NDNS data (years 9–11, 2016/17–2018/19)[41]

Insights into red meat consumption patterns and nutrition from UK purchasing data

Defra Family Food Survey data

Unlike the NDNS, the Family Food Survey (FFS), carried out by the Department for Environment, Food & Rural Affairs (Defra), provides insights into expenditures and purchased quantities of food and drink for consumption within and outside the home. Over the last 40 years, primary red meat consumption has notably declined, with average person consumption in 2023 down 26.1% since 2012.[43] Illustrated in Figure 2 is the average weekly purchases per person from 1980 to 2023, highlighting the decline in primary red meat purchases for beef, lamb and pork, alongside an increase in chicken, while fish purchases remained stable over the past two decades until a decline in 2022 due to rising prices.[43] This provides clear evidence that household consumption of primary red meat has decreased long term in favour of chicken.

Figure 2. Average weekly household purchases (grams per person) of beef, lamb, pork, fish and chicken (1980–2023)

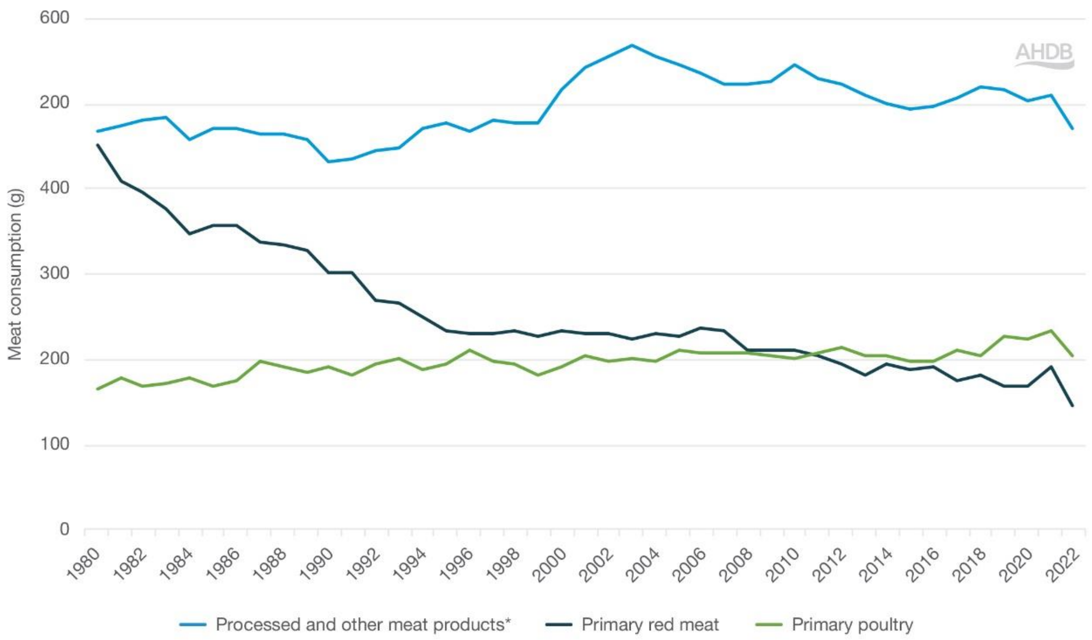


Note: Beef includes joints, steaks, minced and all other beef and veal (except ox liver, corned beef or beef sausages). Lamb includes joints, chops and all other lamb and mutton (except lamb's liver or mutton liver). Pork includes joints, chops, fillets, steaks and all other pork (except pig's liver, bacon, ham and pork sausages). Fish includes white fish, herrings and other blue fish, salmon – all fresh, chilled, frozen, dried, salted or smoked, and shellfish, tinned salmon and other tinned or bottled fish. Chicken includes uncooked chicken.

Source: Defra (2023)[43]

Comparing primary red meat with poultry and processed meats, primary red meats have notably declined, while poultry surpassed primary red meat around 2011 for the first time. Purchases of processed and other meat products have increased (Figure 3), averaging more than double that of red and poultry meat.[43] Since 1980, a clear distinction has emerged between primary red meat and processed meat purchases.[43]

Figure 3. Comparison of household purchases (average grams per person per week) of red meat, poultry and processed and other meat products (1980–2023)



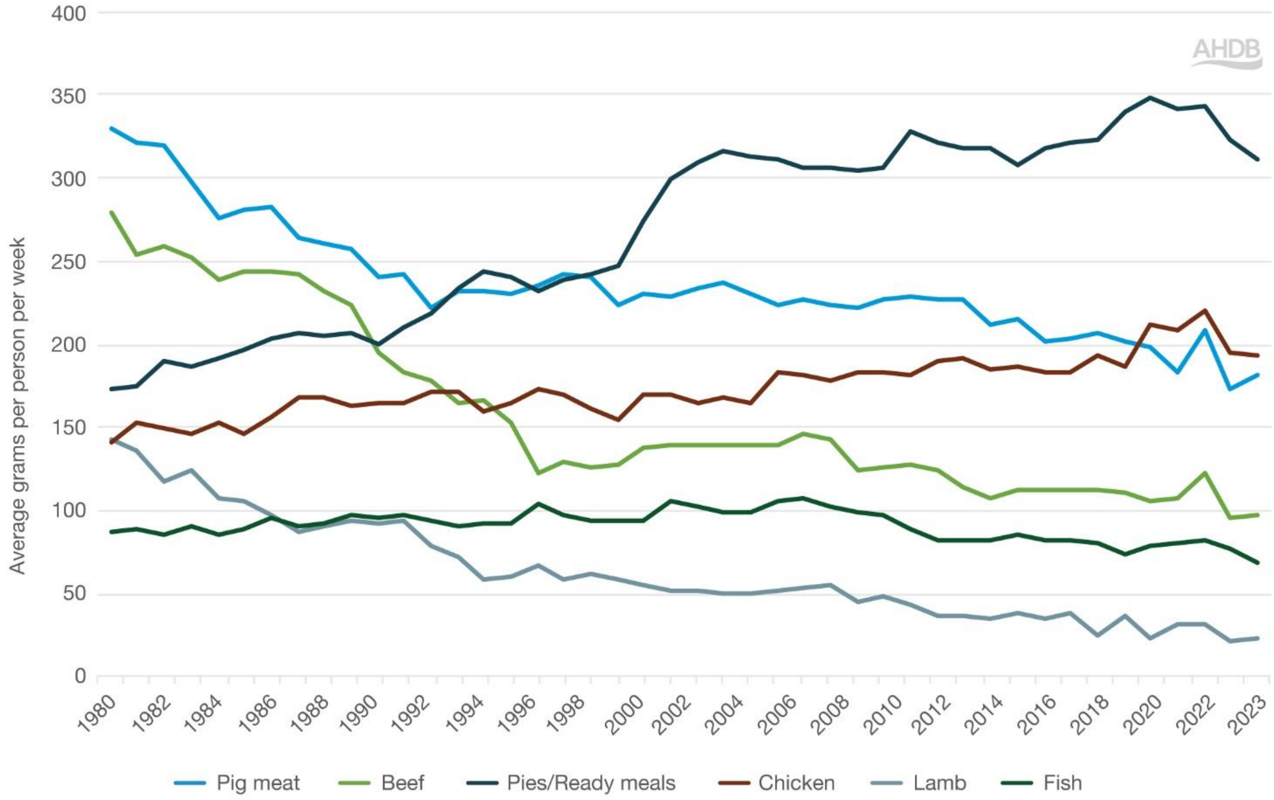
Note: Primary red meat includes beef joints, beef steaks, minced beef, veal, mutton, lamb joints, lamb chops, pork joints, pork chops, pork fillets and steaks and all other non-processed beef, lamb and pork. Primary Poultry includes uncooked chicken and other uncooked poultry. Processed and other meat products include bacon and ham, cooked meat, canned meat, sliced meat, corned meat, sausages, meat pies, sausage rolls, burgers, ready meals and convenience meat products, meat pastes and spreads, and other fresh, chilled and frozen meat.

Data does not include offal, fish or takeaways.

Source: Defra (2023)[43]

Considering this increased consumer preference for more processed foods, Figure 4 compares household purchases of red meat (beef, lamb and pork) with fish, chicken and pies and ready meals combined (1980–2023).[43] The data reveals a downward trend in red meat purchases versus processed pies and ready meals. In 1980, pork was the most purchased, followed by beef, with lamb and chicken on par (Figure 4). However, today, chicken is the most popular, followed by pork.[44]

Figure 4. Comparison of household purchases in the UK (average grams per person per week) of beef, lamb, pork, fish, chicken and pies/ready meals (1980–2023)



Note: Beef includes beef joints, beef steaks, minced beef, ox liver, corned beef and beef sausages. Lamb includes lamb joints, lamb chops, lamb's liver and all other lamb. Pig meat includes pork joints, pork chops, pork fillets and steaks, all other pork, pig's liver, bacon, ham and pork sausages. Fish includes white fish, herrings and other blue fish, salmon – all fresh, chilled, frozen, dried, salted or smoked, and shellfish, tinned salmon and other tinned or bottled fish. Chicken includes uncooked chicken – whole or pieces. Pies/ready meals include meat pies, sausage rolls, pasties, meat puddings, burgers, ready meals and convenience meat products, pâté and delicatessen-type sausage, meat pastes and spreads and ready meals with fish.

Source: Defra (2024)[43]

Why the decline in red meat consumption and purchasing behaviour?

Red meat consumption has consistently declined across all age groups in NDNS surveys,[39] supported by changes in purchasing habits in the Defra FFS. This decline, according to UK consumer data from YouGov, may be attributed to concerns about price, health, animal welfare and the environment, with consumers increasingly viewing chicken and fish as healthier options because they are lower in fat.[44]

The rise in cost of living has made price sensitivity a priority for 78% of consumers,[45] leading them to favour value-for-money options, such as sliced cooked meats, chops and mince. Consequently, processed meat sales (gammon, bacon, sausages) are now significantly higher than primary red meat sales.

Consumers' eating habits within the home are changing from traditional meat and vegetable dishes to more varied world cuisines. While there is a desire for quality and taste within dishes, consumers need them to be quick and simple to prepare. Convenience is key when making food purchasing decisions.

The need for a clear distinction between red and processed meat

The UK Eatwell Guide and the NDNS do not differentiate between red and processed meat, despite their distinct definitions, processing methods, nutritional attributes and associated health risks. This mixed approach complicates the interpretation of research findings and the dietary guidance provided to consumers and policymakers as the Eatwell Guide simply advises reducing consumption of both types of meat, without distinction.[15] There is also added confusion around recommended intake levels, health benefits or risks and environmental factors associated with red or processed meat. To improve clarity, separating processed and red meat in national surveys would enable comprehensive analysis of consumption patterns, nutritional contributions, health risks and benefits, as well as environmental impacts. Such distinctions are essential given the growing awareness of health and sustainability in food choices.

According to the Eatwell Guide, lean unprocessed red meat is a valuable source of key nutrients in the diet, especially for vulnerable population groups, such as children, women of childbearing age, pregnant and breastfeeding women and older adults, as well as elite athletes. UK dietary guidelines should focus on advocating high-quality lean unprocessed red meat as part of a healthy, balanced diet.

Additionally, broader educational and behavioural change initiatives are needed to help the UK population adhere to the recommendations of no more than 70 g of red and processed meat per day. This includes encouraging better dietary choices to reduce calories, saturated fat, salt and sugar, while increasing fibre and essential micronutrients. Incorporating both plant- and animal-based foods, including red meat, can help to provide a better balance of nutrition towards achieving a healthy, balanced diet.

Improving research protocols that distinguish between red and processed meat can yield clearer insights into their specific health risks and environmental concerns. This clarity would help reduce public confusion, guiding consumers towards a healthy, balanced diet and encouraging moderate meat consumption. Such an integrated approach aligns individual health goals with broader environmental sustainability objectives.

References

1. Pobiner, B. (2013). Evidence for meat-eating by early humans. Nature Education Knowledge 4(6): 1.
2. Milton, K. (2003). The critical role played by animal source foods in human (homo) evolution. Journal of Nutrition 133(11 Suppl 2): 3886S–3892S.
3. Leroy, F., Heinrich, F., Lee, M.R.F. et al. (2023). Meat matters – making the case for a valuable food in a hostile environment. Italian Journal of Animal Science 22(1): 885–897.
4. Manzano, P., Rowntree, J., Thompson, L. et al. (2023). Challenges for the balanced attribution of livestock's environmental impacts: the art of conveying simple messages around complex realities. Animal Frontiers 13(2): 35–44.
5. The Dublin Declaration. (2023). The Dublin declaration of scientists on the societal role of livestock. Animal Frontiers, 13(2): 10.
6. Animal Frontiers. (2023). The societal role of meat. Animal Frontiers 13(2): 1–89. Available at: Volume 13 Issue 2 | Animal Frontiers | Oxford Academic (oup.com) (Accessed 2 September 2024).
7. Wyness, L., Weichselbaum, E., O'Connor, A. et al. (2011). Red meat in the diet: an update. Nutrition Bulletin 36(1): 34–77.
8. Williamson, C.S., Foster, R.K., Stanner, S. et al. (2005). Red meat in the diet. Nutrition Bulletin 30(4): 323–355.
9. Linseisen, J., Kesse, E., Slimani, N. et al. (2002). Meat consumption in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohorts: results from 24-hour dietary recalls. Public Health Nutrition 5(6b): 1243–1258.
10. Nutritional aspects of the development of cancer. Report of the Working Group on Diet and Cancer of the Committee on Medical Aspects of Food and Nutrition Policy. Reports on Health and Social Subjects. (1998). 48:i–xiv, 1–274.

11. World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR). (2007). Food, nutrition, physical activity, and the prevention of cancer: a global perspective. Washington DC: AICR.
12. World Cancer Research Fund (WCRF). (2023). Limit red meat and avoid processed meat. Available at: **https://www.wcrf.org/diet-activity-and-cancer/cancer-prevention-recommendations/limit-red-and-processed-meat/ (**Accessed 1 August 2023).
13. American Institute for Cancer Research (AICR). (2024). Limit consumption of red and processed meat. Available at: **https://www.aicr.org/cancer-prevention/recommendations/limit-consumption-of-red-and-processed-meat/** (Accessed 2 September 2024).
14. Scientific Advisory Committee on Nutrition (SACN). (2010). Iron and health. Available at: **https://assets.publishing.service.gov.uk/media/5a7df3dd40f0b62305b7fd53/SACN_Iron_and_Health_Report.pdf (**Accessed 26 October 2023).
15. Public Health England (PHE). (2018). A quick guide to the government's healthy eating recommendations. Available at: **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/742746/A_quick_guide_to_govt_healthy_eating_update.pdf** (Accessed 8 July 2023).
16. Culliford, A.E., Bradbury, J. and Medici, E.B. (2023). Improving communication of the UK sustainable healthy dietary guidelines the Eatwell Guide: a rapid review. Sustainability 15(7*):* 6149.
17. Eating Better Alliance. (2023). It's time to act on processed meat. Available at**: https://www.eating-better.org/site/assets/files/6465/its_time_to_act_on_processed_meat_final-1.pdf** (Accessed 26 October 2023).
18. British Nutrition Foundation (BNF). (2021). Your balanced diet: Get portion wise! – The right types of foods and drinks in the right amounts for you! Full portion size list. London, British Nutrition Foundation.
19. Food Standards Agency (FSA). (2002). Food portion sizes. The Stationery Office, Food Standards Agency.
20. World Health Organization (WHO). (2023a). Red and processed meat in the context of health and the environment: many shades of red and green. Information brief. Geneva: World Health Organization; Licence: CC BY-NC-SA 3.0 IGO.
21. World Health Organization/Food and Agriculture Organization (WHO/FAO) (2003). Joint FAO/WHO expert consultation – Diet, nutrition, and the prevention of chronic diseases. Geneva, Switzerland, World Health Organization. Available at: **https://iris.who.int/bitstream/handle/10665/42665/WHO_TRS_916.pdf?sequence=1** (Accessed 27 October 2023).
22. Food and Agricultural Organization of the United Nations (FAO/WHO). (2019). Sustainable healthy diets – guiding principles. Rome. Available at: **https://www.fao.org/3/ca6640en/ca6640en.pdf** (Accessed 25 September 2023).
23. Herforth, A., Arimond, M., Álvarez-Sánchez, C. et al. (2019). A global review of food-based dietary guidelines. Advances in Nutrition 10(4): 590–605.
24. Nordic Council of Ministers. (2023). Nordic Nutrition Recommendations 2023: integrating environmental considerations. Available at: **https://www.norden.org/en/publication/nordic-nutrition-recommendations-2023** (Accessed 7 November 2023).
25. Healthy and Sustainable Dietary Recommendations, supplemented with physical activity recommendations for the Spanish population. Eat Healthy and take care of your planet. (December 2022).
26. German Society for Nutrition (DGE). (2024). DGE Nutrition Circle: fish, meat, sausage and eggs. Available at: **https://www.dge.de/gesunde-ernaehrung/gut-essen-und-trinken/dge-ernaehrungskreis/** (Accessed 2 September 2024).
27. Federal Ministry Republic of Austria. (2024). Austrian Dietary Recommendations – New. Available at: **https://www.sozialministerium.at/Themen/Gesundheit/Ern%C3%A4hrung/%C3%96sterreichische-Ern%C3%A4hrungsempfehlungen-NEU.html** (Accessed 2 September 2024).
28. Wood, R., Swan, A., Masino, J. et al. (2024). Clearing the confusion: a review of the criticisms relating to the environmental analysis of the Nordic Nutrition Recommendations 2023. Stockholm University. Report. Available at: **https://doi.org/10.17045/sthlmuni.25429057.v1** (Accessed 17 September 2024).
29. Miller, V., Reedy, J., Cudhea, F. et al. (2022). Global, regional, and national consumption of animal-source foods between 1990 and 2018: findings from the Global Dietary Database. The Lancet Planetary Health 6(3): e243–e256.

30. Global Burden of Disease (GBD) Risk Factors Collaborators. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet 396(10258): 1223–1249.
31. Climate Change Committee (CCC). (2020). The sixth carbon budget – the UK's path to net zero. December, 2020. London, Committee on Climate Change.
32. Food Standards Scotland. (2024). Modelling the impact of reductions in meat and dairy consumption on nutrient intakes and disease risk. Available at: **https://www.foodstandards.gov.scot/downloads/Summary_briefing_-_Modelling_the_impact_of_reductions_in_meat_and_dairy_.pdf** (Accessed 13 March 2024).
33. World Health Organization (WHO). (2023b). The Diet Impact Assessment Model (DIA), a tool for analysing the health, environmental and affordability implications of dietary change. Available at: **https://www.who.int/europe/publications/i/item/WHO-EURO-2023-8349-48121-71370** (Accessed 7 November 2023).
34. Willett, W., Rockström, J. et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet Commissions 393(10170): 447–492.
35. Beal, T., Otenzi, F., Fanzo, J. (2023). Estimated micronutrient shortfalls of the EAT–Lancet planetary health diet. The Lancet Planet Health 7(3); e233–237.
36. Hirvonen, K., Bai, Y., Headey, D. et al. (2020). Affordability of the EAT–Lancet reference diet: a global analysis. The Lancet Global Health 8(1): e59–e66.
37. Scheelbeek, P., Green, R., Papier, K. et al. (2020). Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: analyses of multiple UK studies. British Medical Journal Open 10(8): e037554.
38. Steenson, S. and Buttriss, J.L. (2021). Healthier and more sustainable diets: what changes are needed in high-income countries? Nutrition Bulletin 46(3): 279–309.
39. Public Health England (PHE). (2020). NDNS: results from years 9 to 11 (2016 to 2017 and 2018 to 2019). **https://www.gov.uk/government/statistics/ndns-results-from-years-9-to-11-2016-to-2017-and-2018-to-2019** (Accessed 14 July 2023).
40. Public Health England (PHE). (2016). Government dietary recommendations – government recommendations for energy and nutrients for males and females aged 1–18 years and 19+ years. Available at: **https://assets.publishing.service.gov.uk/media/5a749fece5274a44083b82d8/government_dietary_recommendations.pdf** (Accessed 4 January 2024).
41. Spiro, A., Hill, Z. Stanner, S. (2024). Meat and the future of sustainable diets—Challenges and opportunities. Nutrition Bulletin 49(4): 572–598.
42. Stewart, C., Piernas, C., Cook, B. et al. (2021). Trends in UK meat consumption: analysis of data from years 1–11 (2008–09 to 2018–19) of the National Diet and Nutrition Survey rolling programme. The Lancet Planetary Health 5(10): e699–e708.
43. Department for Environment, Food & Rural Affairs (Defra). (2023). Family food datasets: Detailed annual statistics on family food and drink purchases. Available at: **https://www.gov.uk/government/statistical-data-sets/family-food-datasets** (Accessed 2 September 2024).
44. YouGov/Agriculture Horticulture Development Board (AHDB) Tracker Data August 2024, unpublished.
45. Agriculture Horticulture Development Board (AHDB). (2023). Value-tier red meat and dairy sales soar as other tiers suffer. Available at: **https://ahdb.org.uk/news/consumer-insight-value-tier-red-meat-and-dairy-sales-soar-as-other-tiers-suffer** (Accessed 2 September 2024).

3. Nutritional contribution of red meat to UK diets across the lifespan

Summary points:

- Red meat offers a concentrated source of essential nutrients, making moderate portions highly effective in meeting dietary needs. It provides high-quality, bioavailable protein, with all essential amino acids for DNA repair and muscle growth. Additionally, red meat is also rich in bioavailable zinc and vitamin B12 and contains a variety of other B vitamins, vitamin D and selenium. It also contributes monounsaturated fats and omega-3 fatty acids. Lean cuts of meat, when trimmed of visible fat, can be low in total fat and saturated fat
- Protein is important for the growth and maintenance of muscles and the maintenance of normal bones. It consists of 20 different amino acids, nine of which are essential amino acids (EAAs) that must be obtained through diet; the remainder are non-essential and can be synthesised by the body. Animal proteins provide all EAAs, while plant proteins vary in lower proportions, necessitating a mix of sources to meet nutritional needs. Lean red meats such as beef, pork and lamb are high in protein, providing >20 g per 100 g (52–76% protein)
- Red meat not only provides all EAAs but is also rich in branch-chain amino acids (BCAAs), such as leucine which is essential for muscle protein synthesis and preventing muscle breakdown. In contrast, evidence suggests, vegans and vegetarians often have 47% lower levels of circulating amino acids. A complete amino acid profile from plant-based proteins requires careful dietary planning
- High-quality protein intake is important for skeletal muscle health, aiding in disease risk reduction, weight management and meeting increasing protein needs across life stages. While the UK population generally consumes more protein than recommended, focus should be on protein quality and balance, particularly in vulnerable groups, including women of reproductive age, pregnant and lactating women, children and the elderly
- The fat content in red meat varies by type, cut, cooking method and the animal's diet. While often linked to saturated fat, red meat also contains beneficial unsaturated fats, particularly monounsaturated fats
- Grass-fed practices enhance the nutritional quality of red meat compared with intensive, conventional or even organic farming. Grass-fed meat provides better fatty acid profiles with higher omega-3 polyunsaturated fatty acids (PUFAs) and a favourable omega-6 to omega-3 ratio, along with increased levels of essential nutrients such as iron and amino acids
- Saturated fats are associated with an increased risk of cardiovascular disease (CVD), and UK guidelines recommend limiting intake to under 20 g/day. However, the UK population generally exceeds this limit. Cereal products, dairy and meat all contribute 21% each of saturated fat, with only 6% coming from unprocessed red meat. To reduce CVD risks, it is advised to choose lean cuts of red meat, limit processed meat and increase

fruits, vegetables and fibre intake. The decline in fish consumption also highlights the need for alternative omega-3 PUFA sources, with grass-fed beef a potential option

- Red meat, including beef, lamb and pork, is a key source of essential vitamins and minerals. It significantly contributes B vitamins, especially niacin (B3), pantothenic acid (B5), B6 and B12, as well as important minerals, including iron, zinc and selenium – all vital for various health functions
- Vitamin B12 is vital for energy, nervous system and psychological function, immunity, red blood cell formation, homocysteine metabolism and cell division. The recommended intake for adults is 1.5 µg/day, and most adults in the UK average around 5.1 µg/day. While deficiency is low overall, it is notable in specific demographics, particularly children, adolescents and young adult women. The National Diet and Nutrition Survey (NDNS) shows that 5–7% of children aged 4–18 are deficient, with teenage boys having a higher rate (11%) than girls (3%). Among adults, deficiency rates are 7% for those aged 19–64 and 6% for those 65 years and older, with younger women experiencing twice the rate (10%) compared with men (5%)
- Animal-derived foods, particularly meat and meat products, are primary sources of vitamin B12 in the UK diet. Vegetarians and vegans are at higher risk of deficiency due to the exclusion of animal-derived foods and rely on B12-fortified foods and supplements to meet their dietary needs
- Vitamin D supports muscle function, bone health and immunity. The average intake is 2.9 µg/day – below the recommended intake of 10 µg per day. While red meat is not classified as a source of vitamin D, it is a key contributor, providing 8% of vitamin D in adult UK diets, with meat and meat products accounting for 25%
- Iron is crucial for energy metabolism, reducing fatigue, immune and cognitive function, the formation of red blood cells and haemoglobin and oxygen transport. Women of childbearing age need more iron due to menstrual loss. While average daily iron intake is sufficient for adult men and older women, it is insufficient for women aged 19–50. Nearly half of adolescents and a quarter of women aged 19–64 have intake below the lower reference nutrient intake (LRNI). Iron deficiency can progress to anaemia, particularly affecting adolescent girls, with 49% not meeting the LRNI and 9% having iron deficiency anaemia
- Dietary iron comes from animal sources (haem iron) and plant sources (non-haem iron). Red meat, especially beef, is a significant source of haem iron, which is more readily absorbed than non-haem iron from plants. Red meat’s higher bioavailability makes it an important contributor to dietary iron intake, while plant-based iron is absorbed less efficiently and can be inhibited by anti-nutrients such as phytates
- Consuming vitamin C with plant-based foods can enhance absorption of non-haem iron. Adding meat to meals also increases non-haem iron absorption, known as the meat factor. Education on better food choices, and balanced meal planning, including healthy recipes and cooking methods to increase iron intake and absorption, is essential for those reducing or eliminating meat from their diets
- Zinc is vital for macronutrient metabolism, immune function and cognitive performance, with increased needs during growth and breastfeeding. Adult men require more zinc than women, and intake is often below recommended levels, particularly among adolescents, young children and older men. Twenty per cent of adolescent (aged 11–18) boys and 16% of girls have zinc intakes below the LRNI. In children aged 4–10, 15% of girls and 8% of boys are similarly affected. Low zinc intake is concerning due to its importance to fertility, reproduction and cognitive function during these critical life stages

- Red meat is a key source of highly bioavailable zinc, providing 31% of adult intake, and zinc from animal sources is more readily absorbed than from plants. Reducing red meat consumption beyond recommended levels may increase the risk of zinc deficiency, especially in men, highlighting the importance of a balanced diet that includes moderate red meat intake
- Selenium is important for sperm production, thyroid function, protection from oxidative stress and maintaining healthy hair, nails and immune function. Red meat is a significant dietary source of selenium. While average selenium intake in UK adults is below recommended levels, particularly among older women, it has not been flagged as a public health concern. However, hospital admissions for selenium deficiency in England have more than doubled in the past decade, suggesting a rise in clinically significant deficiencies
- The UK faces the challenge of low intake of essential nutrients and excessive unhealthy food consumption, complicating efforts towards healthy sustainable diets. Many plant-based alternatives lack essential nutrients such as vitamin B12, vitamin D, calcium and iodine, raising concerns about nutritional adequacy. While fortification can help, it often does not replicate the complete nutrient profile of whole foods. Educating consumers about varied diets and encouraging gradual dietary changes are crucial to meeting health and environmental goals
- Red meat plays an essential role in a healthy, balanced diet, especially during critical life stages such as pregnancy and lactation. The Food and Agriculture Organization emphasises the role of animal-sourced foods, such as red meat, in meeting global nutritional needs. It provides essential nutrients, including protein, iron and zinc which support maternal health and foetal development during pregnancy and lactation
- A global food composition database study identified that red meat, especially beef and lamb, is nutrient-dense, making it valuable for women of reproductive age and during the first 1000 days of life. Women have higher iron needs due to menstrual blood loss and reduced red meat consumption raises concerns about inadequate iron and zinc intake. This highlights the importance of iron-rich foods like red meat for supporting maternal health and optimising pregnancy outcomes
- Red meat is a valuable source of iron and zinc, positively impacting child growth. Micronutrient deficiencies, particularly iron and zinc, are common among preschool children and women of reproductive age, affecting growth, cognition and immune function
- The growth spurt during puberty increases the demand for essential nutrients such as amino acids, fats, iron and zinc for physical and cognitive development. A diet rich in high-quality protein, B-vitamins and minerals (iron, zinc and selenium) is crucial for reproductive maturation and brain development. Studies show that red meat consumption is associated with improved cognitive function and physical health in schoolchildren, adolescents and older adults
- Maintaining muscle mass to combat sarcopenia (muscle wasting) is critical for older adults, who often face malnutrition and inadequate protein intake. Red meat is recommended as a nutrient-dense food that supports muscle health, cognition and immune function and may help to reduce deficiencies in iron, zinc and B12. A balanced diet with both plant and animal protein sources, combined with regular physical activity, is recommended for healthy ageing

- Sustainable diets that restrict animal-sourced foods, such as the EAT–Lancet Planetary Health diet, can result in low intakes and potential deficiencies in nutrients such as B12, iron and zinc, due to lower bioavailability from plant-based sources. Studies emphasise the need for robust research, including Random Control Trials (RCTs), to evaluate the nutritional impact of these diets across different life stages. Disadvantaged groups are at increased risk for deficiencies, necessitating tailored dietary recommendations. More research is needed to balance the health and environmental impacts of reducing meat while promoting informed and diverse dietary choices

Nutrient composition of red meat

Lean red meat is a rich source of high-quality protein and essential micronutrients that play an important role in promoting good health throughout life. While it contains saturated fats, it also provides more desirable monounsaturated, omega-6 and omega-3 polyunsaturated fatty acids.

The UK Eatwell Guide recommends a healthy, balanced diet based on starchy carbohydrates (potatoes, bread, rice, pasta), at least five servings of fruit and vegetables daily and protein from beans, pulses, fish (two portions per week, one oil-rich), eggs and meat, favouring beans and pulses, while limiting red and processed meat (<70 g). The Eatwell Guide suggests moderate dairy and small amounts of unsaturated oils, while advising to minimise foods high in saturated fat, salt and sugar.[1]

Nutrient composition information is available from different global databases, but it must reflect the specific foods consumed. For example, red meat's nutritional composition can vary by species or breed, age at slaughter, season and feed type; for example, grass-fed animals have higher nutritional value than grain-fed animals.[2,3] In the UK, McCance and Widdowson's Composition of Foods database offers detailed macronutrient and micronutrient information for all the common food and drink items.[4]

Nutrition and health claims

Nutrition and health claims for foods and drinks must comply with the GB Register for Nutrition and Health Claims,[5] aligned with the European Commission (EC) register outlined in the Annex to the retained Directive 90/496/EEC Regulation (EC) No 1925/2006 of the European Parliament and of the Council of 20 December 2006.[6] Specific information about red meat, including allowed claims on its macro- and micronutrient content, will be detailed in the following sections on protein, fat/fatty acids, vitamins and minerals.

Macronutrients in red meat

Macronutrients are essential for energy and many bodily functions. Table 1 summarises the average raw macronutrient composition of the lean red meats (beef, lamb and pork), covering energy, protein fat (saturated and unsaturated) and salt levels.

Beef, lamb and pork provide similar protein levels but differ in energy (calories) and total and saturated fat content. Lean raw lamb has the highest total fat (8.0 g/100 g), twofold higher than beef (4.3 g/100 g), followed by pork with the lowest fat (3.1 g/100 g). A similar pattern holds for saturated fat. Red meat is also naturally low in salt, but processed varieties may contain varying levels depending on the processing methods and the ingredients added (Table 1).

Table 1. Macronutrients and salt in lean beef, lamb and pork (per 100 g), along with recommended intakes and the GB Nutrition and Health Claims criteria

Nutrition	Beef	Pork	Lamb	Recommendation[1]
Energy (kcal)	129	116	153	2,000 kcal/day
Low energy ≤40 kcal/100)[2]	No	No	No	
Protein (g)	22.5	22.2	20.2	45 g/day
(% of protein)	(69.7)	(76.5)	(52.8)	
Rich in protein (>20% of energy) [2] ✓✓	Yes	Yes	Yes	
Fat (g)	4.3	3.1	8.0	70 g/day
Low in fat ≤3 g/100 g[2]	No	No	No	
Saturated fat (g)	1.74	1.04	3.46	20 g/day
(% of total fat)	(40)	(33.5)	(43.2)	(<11 of EI)
Low in saturated fat (≤1.5 g/100 g)[2] ✓	No	Yes	No	
Salt (g)	0.15	0.14	0.17	6 g/day
Low in salt (≤0.3 g/100 g) [2] ✓	Yes	Yes	Yes	

Key: EI – energy intake. All figures provided are lean, raw averages.

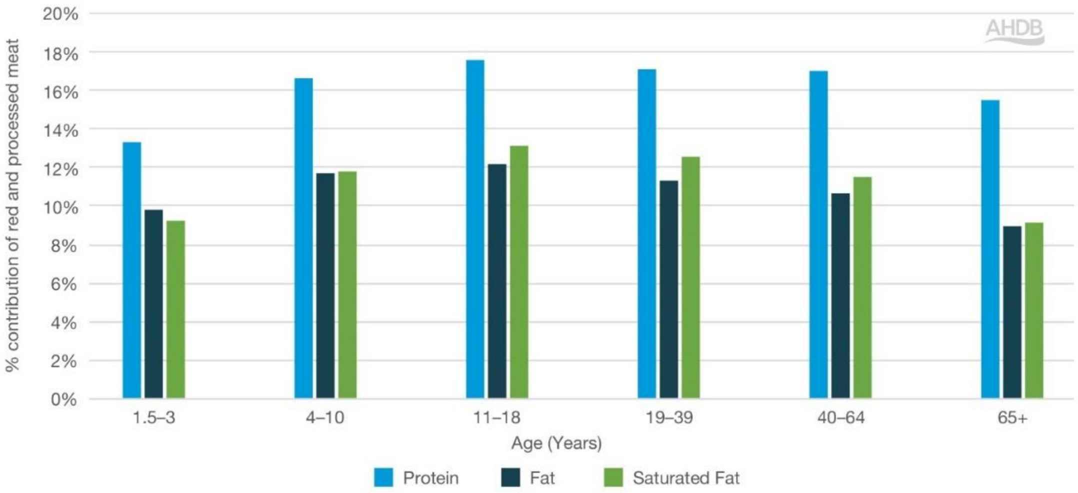
Sources: Food Composition, PHE (2021a)[4]: **https://quadram.ac.uk/UKfoodcomposition/** (Beef; Lamb; Pork), [1]Dietary Recommendations (DH 1991)[7]; [2]Nutrition & Health Claims, DHSC (2023).[5]

Contribution to macronutrient intakes from red and processed meat

Secondary analysis of NDNS data (years 9–11, 2016/17–2018/19) examined red and processed meat consumption in the UK, focusing on adult consumers who ate over 90 g, over 70 g and 70 g per day by gender and age.[8] It also assessed the contribution of red *and* processed meat (excluding the contribution from composite foods) to macronutrient and micronutrient intakes (detailed elsewhere on pages 39 and 60).

Figure 1 highlights the contribution of macronutrients to different age groups, in which the highest contribution to the different macronutrients is consistently observed among those aged 11–18. Lower intake can be seen on either side of the age spectrum in those 1.5–3 years of age and 65+ years of age. However, due to the nature of the data collected within the NDNS report, where there is no clear distinction between red and processed meat, it is not possible to see the contribution made by red meat alone; therefore, the figures reported are expected to be higher, for example, for total fat and saturated fat, with protein values being less clear.

Figure 1: Contribution of red and processed meat to macronutrient intakes



Source: Secondary analysis of NDNS data (years 9–11, 2016/17–2018/19).[8] Red meat was beef, veal and dishes; lamb and dishes; pork and dishes. Processed meat bacon and ham; burgers and kebabs; meat pies and pastries; sausages; chicken was not included

Protein

Protein found in animal-based (red meat, fish, eggs and dairy) and plant-based (soy, beans, pulses, lentils, nuts and seeds) foods is essential for the normal development, growth and maintenance of both muscles and bones in children.[5,6] To be labelled as a source of protein, a food must provide 12% of its energy value from protein, while a high in protein nutrition claim requires 20%.[5]

Protein structure and amino acid content

Proteins consist of long chains of amino acids – the building blocks of protein. There are 20 amino acids; nine are essential amino acids (EAAs) that must be obtained from the diet, while the remaining non-essential amino acids can be synthesised by the body (Table 2).[9]

Table 2. Essential and non-essential amino acids

Essential amino acids	Non-essential amino acids
Histidine	Alanine
Isoleucine*	Asparagine
Leucine*	Arginine
Lysine	Cysteine
Methionine	Aspartic acid
Tryptophan	Glutamic acid
Threonine	Proline
Valine*	Tyrosine
Phenylalanine	Serine
	Glycine

Key: * – Branch-chained amino acids

Source: Wu (2009)[9]

Amino acids

Although the body can produce non-essential amino acids either from the essential amino acids or intermediates from metabolic pathways, insufficient protein intake can lead to malnutrition. Animal proteins, such as those found in meat, provide all essential amino acids and have a favourable amino acid profile comparable to human cells.[10] In contrast, plant-based protein sources have a proportionally lower distribution of essential amino acids, meaning that the quantity and combination of a variety of plant-based proteins are important throughout the day. For example, grains are low in lysine, while legumes lack methionine. Therefore, consuming the right quantity and variety of different plant-based proteins will ensure that essential amino acid requirements are met.[11]

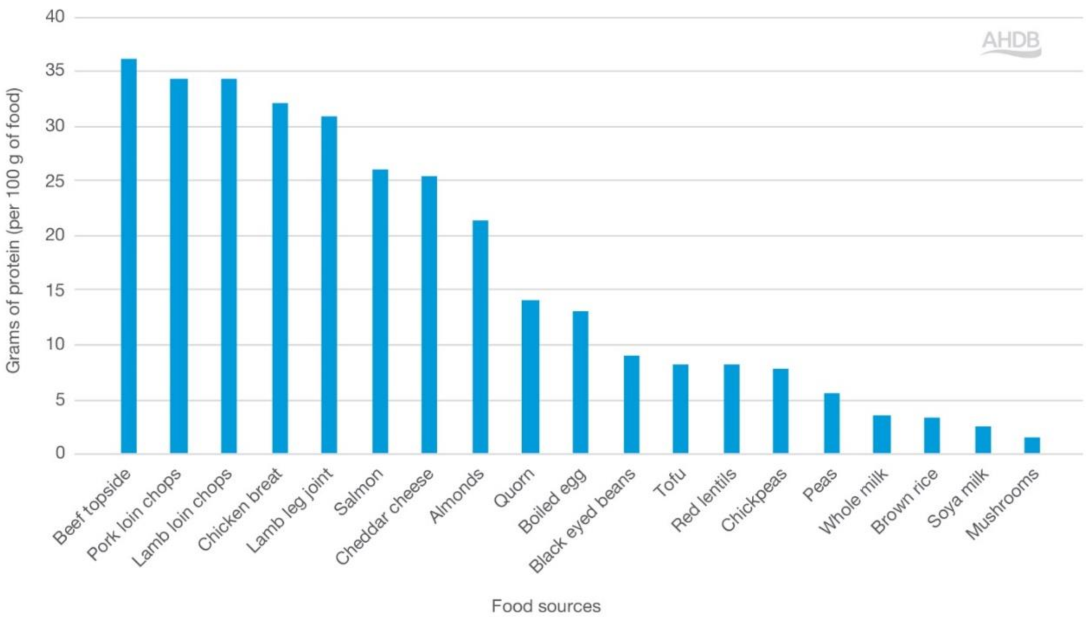
Leucine, isoleucine and valine are essential amino acids with aliphatic side chains, classifying them as branch-chain amino acids (BCAAs). These BCAAs are crucial for protein synthesis,[12] with leucine being the key driver of post-meal muscle protein synthesis, known as the leucine trigger hypothesis. Consuming leucine-rich foods effectively stimulates this process.[13,14] A systematic review indicated that the leucine trigger hypothesis has greater benefits for stimulating muscle protein synthesis (MPS) in older adults compared with younger adults.[15] Within older adults in particular, higher protein intakes can reduce the decline in muscle mass commonly seen with ageing.[16]

Skeletal muscle is vital for overall health, influencing metabolic health and sports performance. It correlates positively with muscle mass and strength, while also reducing the risk of non-communicable diseases, including obesity, cardiovascular disease (CVD), diabetes and osteoporosis.[14,17] Protein is important for maintaining lean body mass, stimulating muscle protein synthesis, preventing sarcopenia (muscle wasting) and aiding weight management through satiety. However, meeting protein needs requires attention to BCAAs, particularly leucine, as well as protein quality, timing and physical activity for optimal synthesis. Leucine and other BCAAs as part of high-quality protein intake are vital for muscle protein synthesis and the prevention of muscle breakdown.[18]

Protein quantity and quality in red meat

Red meat is a valuable protein source, offering higher protein content and a better amino acid profile compared with plant-based foods (see Figure 2). While various protein sources exist, understanding their differences is crucial. Meat provides essential nutrients, including iron, zinc, vitamin B12 and selenium, but lacks fibre. In contrast, plant sources of protein offer fibre and micronutrients, such as folate, but have a narrower amino acid profile and lack haem iron and vitamin B12. Therefore, consuming a variety of both types of foods, ideally together, can enhance nutritional balance. As illustrated in Figure 2, beef, pork and lamb provide approximately 30–36 g of protein per 100 g, varying by type and cut. Other animal proteins can also contribute significantly, while plant sources of protein, such as meat alternatives, beans, chickpeas, lentils and mushrooms, offer lower protein levels.

Figure 2. Protein content of different animal and plant-based food sources (per 100 g)



Source: Adapted from McCance and Widdowson data[4]

Amino acids in red meat

Meat is a rich source of protein[19] and essential amino acids, notably lysine, threonine and methionine, which are often limited in plant-based diets.[20] As illustrated in Table 3, beef and lamb provide around 3.5–4 times the average daily adult requirement for lysine, threonine and methionine, with lamb offering 182 mg and beef 172 mg of lysine per gram of protein per day.

BCAAs leucine, isoleucine and valine are also much more abundant in animal proteins, particularly red meat. Leucine is the most abundant of the three BCAAs (Table 3) and is crucial for meeting adult amino acid requirements (59 mg/g of protein),[21] particularly as leucine is the amino acid of highest adult need. Beef and lamb supply over 2.5 times the requirement at approximately 167 mg/g, while soy or pea protein provide 77 or 57 mg/g of protein, respectively. The WHO/FAO/United Nations University (UNU) (2007)[21] guidelines recommend BCAA intakes of 85 mg per kg of body weight per day for adults, although this is thought to be higher for athletes and those who exercise regularly.[18] Lamb provides 370 mg and beef 358 mg/g of protein, compared with 106 mg for pea protein (Table 3).

Tryptophan, an amino acid important for serotonin production and mood and sleep regulation,[22] is the least abundant amino acid. Animal sources such as beef and lamb provide four times the average adult requirement compared with soy protein. Some plant-based proteins, such as pea and brown rice, lack tryptophan (Table 3). Lean beef brisket contains 20 times more tryptophan than chickpeas, kidney beans and lentils and 10 times more than nuts, including almonds, peanuts and walnuts (USDA Food Data Central 2022, cited in Derbyshire et al., 2023).[23]

Table 3. Daily adult essential amino acid requirements and protein food sources

Essential amino acid	Average adult requirements[1](mg/g protein/day)	Food (mg/g of protein)						
		Beef[2]	Lamb[2]	Milk[3]	Egg[1]	Soy protein[3]	Pea protein[4]	Brown rice protein [4]
Lysine	45	172	182	80	66	60	47	19
Leucine*	59	167	165	97	83	77	57	58
Isoleucine*	30	93	96	50	51	48	23	20
Valine*	39	98	109	58	48	47	27	28
Phenylalanine	38	86	84	99	60	52	37	37
Threonine	23	82	103	47	48	36	25	23
Histidine	15	85	43	30	24	26	16	15
Methionine	16	68	68	27	35	13	3	20
Tryptophan	6	25	22	13	18	13	-	-

Key: * – branch chain amino acids. Note: Other protein sources, such as nuts and seeds, were not included in the source provided. However, put in context, the foods illustrated can apply to main meal provisions as opposed to snacks.

Source: Taken directly from Beef and Lamb New Zealand (2022)[24];

[1]WHO/FAO/UNU (2007)[25] based on a mean nitrogen requirement of 105 mg of nitrogen/kg per day (0–66g of protein/kg per day)

[2] Purchas et al. (2013)[26]

[3] Kalman (2014)[27]

[4] Gorissen et al. (2018)[28]

Evidence suggests plant-based foods generally have lower protein content and provide fewer EAAs and BCAAs (see Table 3), requiring greater variety of food sources and in greater quantity to meet nutritional needs. For instance, pistachio nuts provide all nine EAAs[23]; however, they are rarely consumed, with only 0.4% of men and 0.7% of women in the EU consuming them.[29] Typical portion sizes are around 22–23.1 g per day – much smaller than portions of red meat. The EPIC study shows that vegans have 47% lower blood plasma amino acids than meat eaters, with methionine, tryptophan and tyrosine being particularly low.[30] Therefore, individuals transitioning to a plant-based diet must carefully plan their meals to ensure a varied intake of protein sources and in sufficient quantities to meet the body's amino acid requirements.

Essential amino acid functions within the body

Amino acids play various roles in the body, including protein synthesis, energy metabolism, neurotransmitter synthesis, collagen formation and hormone synthesis.[22] However, there are no approved nutrition and health claims for amino acids under GB/EU standards.[5] Prolonged deficiency in essential amino acids can lead to growth failure, muscle loss and organ damage,[22] with deficiencies being more common in developing countries.[31]

Understanding protein quality

When assessing protein quality, it is essential to consider how well the body absorbs and digests proteins. Animal proteins have higher digestibility (>95%) compared with plant protein (50–80%), largely attributed to a better distribution of essential amino acids.[32,33] Protein quality can be measured using the Protein Digestibility-Corrected Amino Acid Score (PDCAAS),[34] which accounts for amino acid requirements and digestibility. A maximum score of 1.0 indicates that a protein meets the minimum essential amino acid requirements for tissue growth and maintenance.

The Digestible Indispensable Amino Acid Score (DIAAS) is an alternative method for assessing protein quality, recommended by the FAO.[35] It focuses on the digestibility and absorption of essential amino acids, with a score above 100 indicating excellent protein quality, and scores between 75 and 99 considered a good protein source.

A comparison of the two assessment methods and the protein scores obtained from different foods (Table 4) reveals a distinct difference between plant-based and animal-based proteins. Animal proteins, such as milk and meat, achieve higher DIAAS scores; for example, lean beef scores 111, compared with peas at 58.

Cooking methods also affect protein quality.[36] Combining plant proteins with lower DIAAS scores with higher-scoring animal proteins can create balanced meals that fulfil amino acid requirements.[37] For instance, adding beans, pulses, legumes or lentils to meat dishes or substituting them for a proportion of meat increases fibre content and complements the micronutrients present.

Table 4. Protein quality of commonly consumed foods assessed by PDCAAS and DIAAS methods

Protein source	PDCAAS	DIAAS
Cow's milk (whole milk)	1.0	114
Egg (hard boiled)	1.0	113
Lean beef (raw)	1.0	111
Chicken breast	1.0	72
Soy protein isolate	0.90	98
Cooked kidney beans	0.65	59
Cooked rice	0.62	59
Cooked peas	0.60	58
Wheat	0.46	40.2

Key: PDCAAS – Protein Digestibility-Corrected Amino Acid Score; DIAAS – Digestible Indispensable Amino Acid Score: >100 = excellent protein quality.

Factors influencing amino acid concentration and uptake

The nutritional quality of animal-based foods, particularly red meat, is influenced by feeding practices and cooking methods. For example, grass-fed Welsh lambs showed higher concentrations of the essential amino acids (leucine, lysine, threonine, tyrosine and valine) compared with grain-finished lambs.[38] Cooking methods also affect amino acid absorption; for example, raw, boiled and pan-fried beef scores higher on the DIAAS than roasted or grilled beef. However, beef consistently remains a high-quality protein source, irrespective of the cooking method used.[36]

A study involving 16 older adults (aged 65 to 85) found that consuming a beef-based meal resulted in 127% higher-circulating amino acid levels compared with a vegan meal of equal protein content.[39] Muscle protein synthesis was also 47% higher after the beef meal. The findings suggest that the higher digestibility of meat proteins contributes to increased amino acid levels in the blood and highlights a need for further research on protein types, especially for older adults and athletes, to ensure adequate intake of essential amino acids. Larger quantities of plant-based protein do not guarantee amino acid requirements will be met.

Potential benefits of meat compounds beyond amino acids

In addition to amino acids, meat provides bioactive metabolites and peptides derived from amino acids, such as taurine, creatine, hydroxyproline, carnosine and anserine, that are absent in plants. These compounds contribute to antioxidative, anti-inflammatory and various physiological functions in neurological, muscular, retinal, immunological and cardiovascular systems, as reviewed by Wu (2020).[40] Despite increasing interest, the UK food composition database lacks data on these compounds.[4] Current health claims authorised in the UK[5] are limited to creatine for physical performance, with no approvals for taurine and no applications for hydroxyproline and anserine.[5]

Human protein requirements

Protein needs in the UK, detailed in Table 5, vary by age and stage. Young children require more protein per body weight for growth and development, while pregnant and lactating women have higher requirements for themselves and their babies. Generally, males have greater protein requirements than females. The standard calculation is 0.75 g per kg of body weight. For instance, a person weighing 60 kg needs approximately 45 g of protein per day (60 kg x 0.75 g = 45 g/day). These guidelines were based on average body weights from 1991.[7]

Table 5. UK dietary reference values (DRVs) for protein

Age and gender		Weight (kg)	Adequate intake	
			Estimated average requirement (EAR) (g/day)	Reference nutrient intake (RNI) (g/day)
Infants	0-3 months	5.9	-	12.5
	4-6 months	7.7	10.6	12.7
	7–9 months	8.8	11.0	13.7
	10–12 months	9.7	11.2	14.9
Children	1–3 years	12.5	11.7	14.5
	4–6 years	17.8	14.8	19.7
	7–10 years	28.3	22.8	28.3
Males	11–14 years	43.0	33.8	2.1
	15–18 years	64.5	46.1	55.2
	19–64 years	74.0	44.4	55.5
	64–75$^+$ years	71.0	42.6	53.3
Females	11–14 years	43.8	33.1	41.2
	15–18 years	55.5	37.1	45.4
	19–64 years	60.0	36.0	45.0
	64–75$^+$ years	62.0	37.2	46.5
	Pregnancy	-	-	+6
	Breastfeeding 0–6 months	-	-	+11
	Breastfeeding 6+ months	-	-	+8

Key: EAR – estimated average requirements: the amount needed to meet the needs of just half of the population; therefore, it is unlikely to be sufficient for the rest of the population. RNI – reference nutrient requirements: the amount needed to meet the needs of most people; therefore, intakes are unlikely to be deficient. Protein requirements = 0.75 g of protein per kg of body weight, e.g. 60 kg x 0.75 g = 45 g/day. Protein requirements during pregnancy and breastfeeding must be added to female adult requirements, i.e. the pregnancy calculation is 45.0 + 6 = 51 g/day.
Source: Adapted from DH (1991)[7] and PHE (2016)[41]

The National Diet and Nutrition Survey (NDNS) (years 9–11, 2016/17–2018/19) shows that adults aged 19 to 64 have an average protein intake of 76 g per day, while those aged 65 to 74 consume about 69 g per day, decreasing to 63 g in those 75 and older (Table 6).[42] On average, people in developed countries, including the UK, meet and often exceed the reference nutrient intake (RNI) for protein; for example, UK children aged 1.5–3 years have an RNI of 14.5 g per day (Table 5) but consume 41 g per day (Table 6). Similarly, for those aged 4–10, the RNIs are 19.7 (ages 4–6) and 28.3g (7–10) per day (Table 5), with the average around 52.6 g per day (Table 6).

Excessive protein intake can lead to kidney stones in adults and has been associated with increased BMI in children.[43] While the UK's protein consumption is sufficient, it is important to obtain protein from a variety of foods, including both animal and plant-based options, to ensure a balanced diet rich in micronutrients and dietary fibre.

Table 6. Average daily protein intake (g/day)

	1.5–3 years	4–10 years	11–18 years	19–64 years	65–74 years	75+ years
Average daily protein intake (g/day)	41	52.9	64.5	76	69.3	63.4

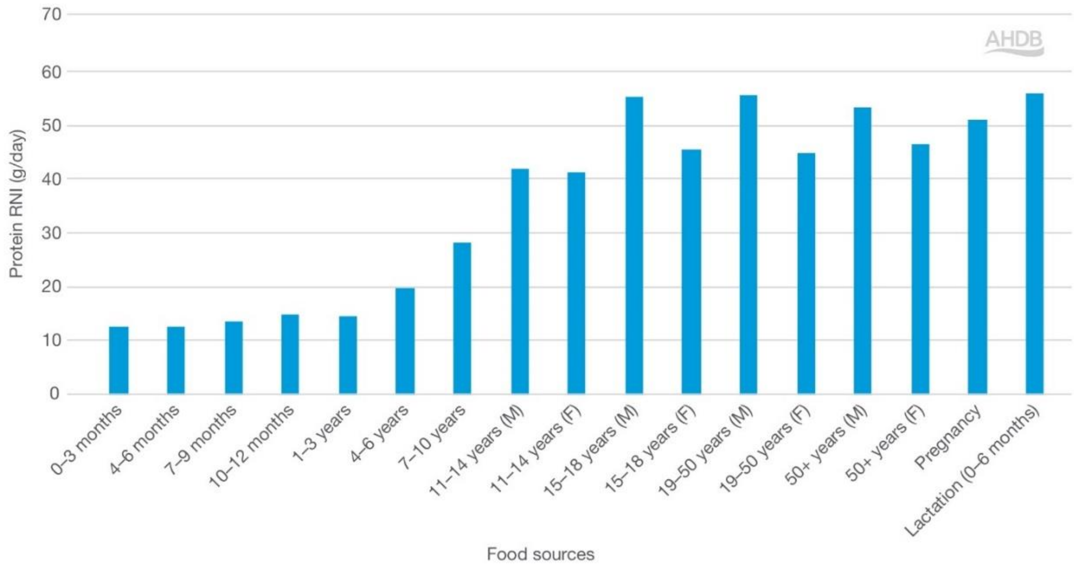
Source: NDNS[42]

Individual protein needs can vary by life stage, growth and physical activity, putting vulnerable groups at risk of inadequate protein intake. Daily protein is crucial to prevent muscle breakdown, especially for those in lower-income countries and individuals with specific dietary requirements, such as vegans, and those experiencing food insecurity are at higher risk of inadequate or lower-quality protein intake.[44,45,46]

The FAO's 2024 State of Food Security and Nutrition report reveals that, globally, 46.7% of women aged 15–49 are severely food insecure, with 60.9% moderately secure and 77.7% food secure or mildly insecure.[45] This highlights the complex relationship between food insecurity and diet quality, influenced by food environments, consumer behaviour and the cost of a healthy diet. Food insecurity often leads to malnutrition, particularly in women, and is linked to lower nutritious food intake and higher consumption of unhealthy energy-dense foods. In the UK, 14% of adults (~11.3 million people) experience food insecurity, increasing food bank use and impacting diet quality.[47,48] While less prevalent in Europe and North America, food insecurity is on the rise, with nearly 10% of adults experiencing moderate to severe food insecurity.[45]

Research indicates that vegans often consume less protein compared with other dietary groups, increasing the risk of insufficient protein intake, especially if their consumption of legumes, nuts and seeds is low.[46] This results in significantly lower blood plasma amino acid levels compared with meat eaters,[30] suggesting poorer protein quality.[49] Figure 3 summarises protein requirements, showing increased needs in infancy and puberty, particularly for males, as well as for pregnant and breastfeeding women. Ensuring adequate high-quality protein intake during these critical life stages is essential. Vulnerable groups – including young and old adults, those who are ill and individuals requiring extra protein for development and growth and healthy ageing– need special attention to meet their protein needs. Higher protein requirements (>0.75 g of protein per kg) are detailed in Table 7. Further discussion on meeting the nutritional needs of these vulnerable groups is provided later in this report.

Figure 3. Protein reference nutrient intakes throughout life



Key: RNI – reference nutrient requirements: the amount needed to meet the needs of most people; therefore, intakes at this level are unlikely to be deficient. Protein requirements = 0.75 g of protein per kg body weight, e.g. 60 kg x 0.75 g = 45 g/day. Maximum protein requirements during breastfeeding are shown.

Source: DH (1991).[7]

Table 7. Additional protein requirements within specific population groups

Population group	Protein requirements (g per kg)
Young adults[1,2]	0.8
Older adults[3]	1.0–1.2
Athletes[4]	1.0–2.0

Sources: [1] DH (1991)[7]; [2] PHE (2016)[41]; [3] Bauer et al. (2013)[50]; [4] Jäger et al. (2017)[13]

Protein content within red meat

Red meat is a 'rich protein source', contributing 52–76% of energy. Lean, raw beef, lamb or pork provides about 20–22 g of protein per 100 g, which is half the recommended intake (Table 1; Table 8). Cooking increases the protein content due to the reduced water content concentrating the nutrients present.[10]

Table 8. Protein in red meat (beef, lamb and pork) (per 100 g)

Nutrition	Beef	Pork	Lamb	Recommendation[1]
Protein (g)	22.5 (69.7%)	22.2 (76.5%)	20.2 (52.8%)	45 g/day
(Rich source ≥20% energy value of the food is provided by protein ✓✓)[2]	Yes	Yes	Yes	

Sources: Food Composition, PHE (2021a)[4]: **https://quadram.ac.uk/UKfoodcomposition/** (Beef; Lamb; Pork), [1]Dietary Recommendations (DH 1991)[7]; [2]Nutrition & Health Claims, DHSC (2023)[5].

Protein intakes from red and processed meat

The NDNS survey (Years 9–11, 2016/17–2018/19) indicates that protein intake exceeds recommended levels across all age groups.[42] Therefore, the focus should be on protein quality rather than quantity within the overall diet. When considering protein sources, it is important to compare red meat with processed meats and non-animal-sourced protein foods (Table 9). The NDNS data shows that non-animal foods[42] contribute more than double or even triple the protein of red and processed meat, surpassing the total protein contribution from all meat and meat products (Table 9, Figure 4).

Table 9. The comparison of protein contributions made by red and processed meats and non-animal foods

Age (years)	Red meat[1]	Processed meat[2]	Other meat[3]	Total meat and meat products	Other non-animal protein-containing foods[4]
1.5–3	5%	6%	12%	23%	38%
4–10	7%	9%	14%	29%	43%
11–18	9%	10%	18%	37%	42%
19–64	10%	8%	16%	34%	40%
65–74	11%	7%	13%	30%	38%
75+	10%	7%	13%	31%	37%

Source: Calculated using the most recent NDNS data.[42]

Note: [1] Red meat included beef, veal, and dishes; lamb and dishes; pork and dishes

[2] Processed meat included bacon and ham, burgers and kebabs, meat pies and pastries, and sausages

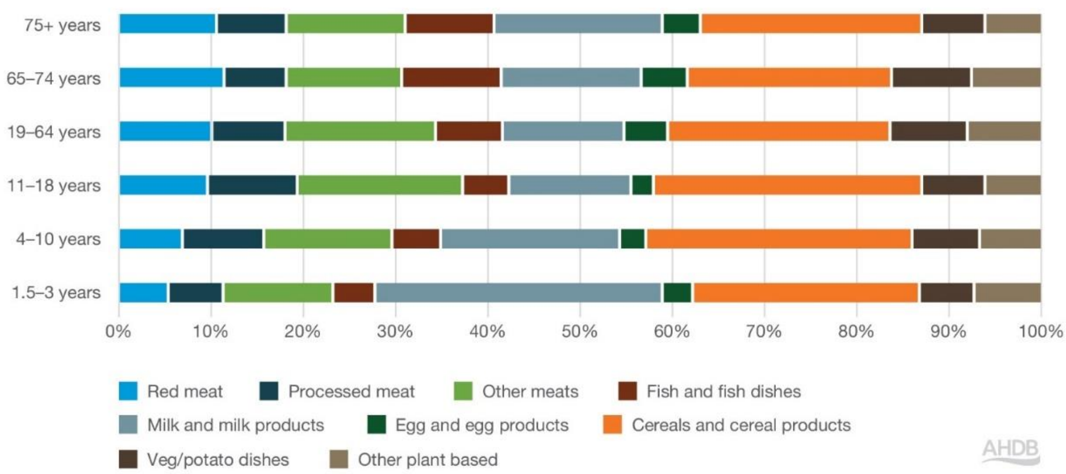
[3] Other meat included coated chicken and turkey; chicken, turkey and dishes; liver and dishes; other meat, meat products and dishes

[4] Estimated plant-based proteins included cereals and cereal products, vegetables and potatoes, and other plant-based protein sources. Although some of these foods are not proteins per se, they were included because of their contribution to protein within the diet

Despite the higher protein levels, it is important to consider the quality of protein, including the amino acid contribution, digestibility and absorption of other non-animal protein sources compared with red meat, as described earlier. Optimal muscle protein synthesis requires balanced protein intake throughout the day, making it essential to consume a variety and larger portion sizes of plant-based proteins to offset their lower protein quality.

According to the NDNS (years 9–11, 2016/17–2018/19),[42] red and processed meat contribute to 34% protein intake for UK adults aged 19–64, followed by cereals and cereal products (24%) and milk products (13%). This contribution is significantly higher in those aged 11–18 at 37%.

Figure 4. Main food contributors to dietary protein intakes



Source: Calculated using the most recent NDNS data (PHE 2020).

Note: Milk and milk products include whole milk (3.8% fat), semi-skimmed milk (1.8% fat), other milk and cream, cheese (Cheddar; other), yogurt, fromage frais and other dairy desserts, and ice cream

Cereals and cereal products include pasta, rice, pizza and other miscellaneous cereals; white bread; wholemeal bread; brown, granary and wheatgerm bread; high-fibre breakfast cereals; other breakfast cereals; biscuits; buns, cakes, pastries and fruit pies; puddings

Red meat included beef, veal and dishes; lamb and dishes; pork and dishes
Processed meat included bacon and ham, burgers and kebabs, meat pies and pastries, and sausages
Other meat included coated chicken and turkey; chicken, turkey and dishes; liver and dishes; other meat, meat products and dishes

Vegetables and potatoes included salad and other raw vegetables; vegetables (not raw) including vegetable dishes; chips, fried and roasted potatoes and potato products; other potatoes, potato salads and dishes

Eggs and egg dishes included manufactured egg products including ready meals; any type of manufactured/retail egg dishes including ready meals: quiches, flans, Scotch eggs, meringue, pavlova, curried eggs, egg mayonnaise sandwich filler; other eggs and egg dishes including homemade; Includes all types of egg (duck, hen and goose): boiled, fried, scrambled, poached, dried, omelettes (sweet or savoury) and eggy bread. Includes any homemade egg recipe dish.

Other plant-based foods providing protein included savoury snacks; nuts and seeds; fruit; sugar preserves and confectionery; fruit juice; tea, coffee and water; and miscellaneous

When separating red meat from processed meat (Figure 4), in adults aged 19–64, red meat contributes 10% of protein intake, compared with 16%, from other meats, primarily chicken and turkey. The top protein sources for this age group are cereals and cereal products (24%), milk and milk products (13%) and other meats (16%). Red meat ranks fourth at 10%, similar to vegetable and potato dishes, and other plant-based proteins and processed meat both at 8%, while fish contributes 7% and eggs 5%. In very young children (1.5–3 years), milk and milk products provide the most protein (31%), while cereals and cereal products (18%) are the largest for those under 18.

With concerns behind recommendations to reduce red meat consumption, research from the Canadian Community Health Survey (2015) found that adults relying heavily on plant-based proteins (~75–100% from plant foods) did not meet the recommended protein intake of 0.8 g/kg grams of body weight.[51] The UK's recommendation is slightly lower, at 0.75 g/kg.

While some studies suggest adequate protein intake among plant-based diets,[46] a systematic review of 64 studies showed that vegetarians and vegans consume less protein (13.4% and 12% of energy, respectively) compared with meat eaters (16%).[52] Current protein recommendations, based on nitrogen content, do not account for the specific functions of amino acids.[53] Therefore, those on restrictive vegan diets may risk inadequate protein intake. A better understanding of amino acid composition, such as the new EAA-9 scoring method,[53] could help evaluate the EAAs' contributions of different foods and optimise protein intake to prevent long-term health issues.

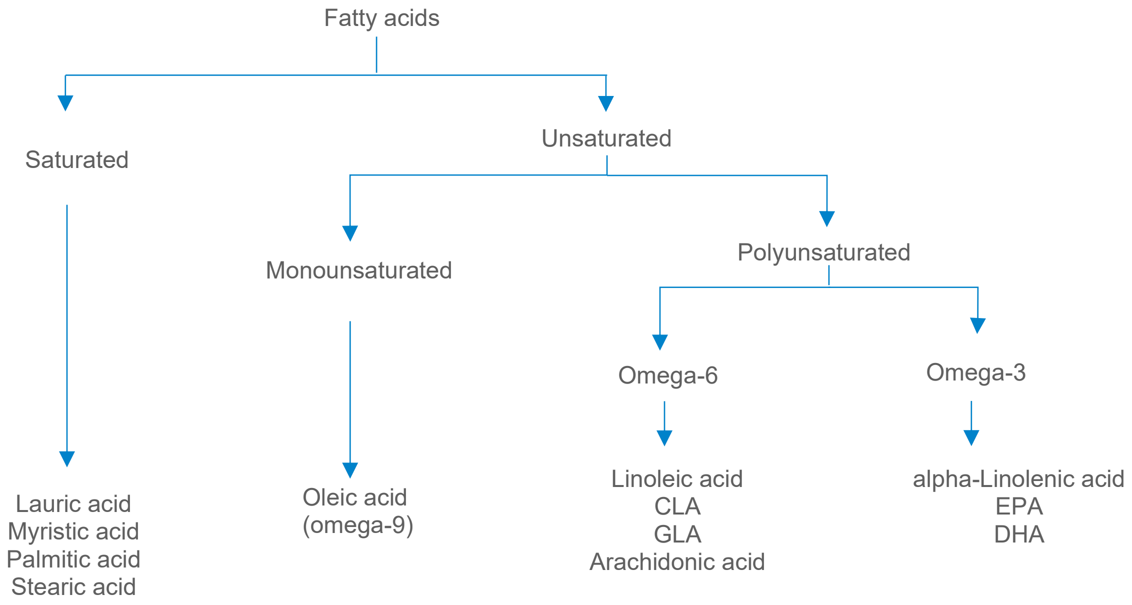
Fat

Fat is a vital energy source that aids in the absorption of fat-soluble vitamins (A, D, E and K) and provides essential omega-3 and omega-6 polyunsaturated fatty acids, which the body cannot produce. Fat also protects organs and promotes cell growth. However, excessive fat consumption increases the risk of becoming overweight and obese, along with the associated health implications. Beyond its nutritional role, fat enhances food palatability, improving mouthfeel, succulence and flavour.

Fatty acid profile of red meat

Fatty acids are a subclass of fat, either consumed in the diet or synthesised in the body, and classed as either saturated, monounsaturated or polyunsaturated according to their chemical structure. Fatty acids are created by linking carbon atoms together to form short or long fatty acid chains. Saturated fatty acids have no double bond in their carbon chain, while unsaturated fats have one and polyunsaturated fatty acids (PUFAs) have two or more. PUFAs are categorised further into two families: omega-3 and omega-6, based on the position of their first double bond: omega-3 at the third carbon and omega-6 at the sixth carbon.[55] The body cannot synthesise the short-chain essential fatty acids alpha-linolenic (omega-3) and linoleic acid (omega-6), so they must be obtained through the diet. Saturated fats are typically found in animal products (meat and dairy), certain oils (palm, coconut), spreads (butter, ghee) and processed foods (biscuits, pies, cakes, pizzas and pastries).[42] Red meat contains around 30–40% monounsaturated fat, typically oleic acid (omega-9).[54] While PUFAs within red meat are mainly linoleic (omega-6) and alpha-linoleic (omega-3) and are present in much smaller amounts. When the essential short-chain omega-3 fatty acid alpha-linolenic is consumed, it can be converted into the long-chain eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), both of which have important health benefits and are discussed in detail later.

Figure 5. An overview of the different family of fatty acids found in the fat of red meat



Key: CLA – conjugated linoleic acid; GLA – gamma linolenic acid; EPA – eicosapentaenoic acid; DHA – docosahexaenoic acid. Source: https://www.examplesof.net/2014/06/example-of-saturated-fatty-acids-and.html

The fat content of red meat is subject to variation based on type, cut, degree of trimming and cooking methods. Generally, frying or roasting increases fat levels compared with stewing or grilling. Fat is the most calorie-dense macronutrient and provides 9 kcal per gram, while carbohydrates and protein provide 4 kcal per gram. Consequently, red meat with higher fat content cooked with added fat will yield more calories.

While many consumers associate animal foods with being high in saturated fat, red meat contains significant amounts of unsaturated fats, particularly monounsaturated fats. Red meat typically consists of 40% saturated fats, 40% monounsaturated fats, 5% trans fats (with raw lean lamb and beef at 0.01% and 3.25%, respectively) and 4% polyunsaturated fats. However, these proportions will depend on the aforementioned factors.[4] Additionally, effective animal feeding strategies can improve the fatty acid profile of pork,[56] beef[3,56] and lamb[38] and are discussed in detail later.

Nutrition and health claims for the different types of fat in food and drink are outlined in the GB Register for Nutrition and Health Claims.[5] Those relevant to red meat include claims relating to saturated and unsaturated fats as well as omega-3 profiles (see bullet points below).

- To qualify as low in saturated fat, the food product must contain ≤1.5 g of saturated fat per 100 g
- Claims of being high in monounsaturated or polyunsaturated fats can only be made when the food product contains at least 45% of the total fatty acids present and they contribute >20% of the product’s energy
- To qualify as a source of omega-3 fatty acids, the product must contain at least 0.3 g of alpha linolenic acid per 100 g and per 100 kcal or at least 40 mg of the sum of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) per 100 g and 100 kcal. To claim that a food is high in omega-3 fatty acids, this doubles to 0.6 g for alpha linoleic or at least 80 mg of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)

Fat composition of red meat

Based on lean, raw meat averages, the fat profile of beef, pork and lamb is summarised in Table 10. Lamb contains 8 g of fat per 100 g of meat, while beef and pork have 4.3 g and 3.1 g, respectively. Less than half the fat in red meat is saturated (43–33%), pork is considered low in saturated fat at 1.04 g/100 g (≤1.5 g/100 g), while beef just exceeds this at 1.74 g/100 g. Lamb contains almost twice as much saturated fat as pork and beef at 3.46 g/100 g.

Table 10. The energy and fat profile of beef, pork and lamb

Nutrition	Beef[1]	Pork[1]	Lamb[1]	Recommendations3
Energy (low ≤40 kcal/100 g)[2]	129 kcal No	116 kcal No	153 kcal No	2,000 kcal/day
Fat (g) (low ≤3 g/100 g)[2]	4.3 No	3.1 No	8 No	70 g/day (≤35% of EI)[3]
Saturated fat (g) (% of total meat fat) (low ≤ 1.5 g/100 g)[2]	1.74 40.5 No	1.04 33.5 yes	3.46 43.2 No	20 g/day (≤10% of EI)[4]
Monounsaturated fat (g) (% of total meat fat)	1.87 43.5	1.24 40	3.09 38.6	(13% of EI)[3]
Polyunsaturated fat (g) (% of total meat fat)	0.23 5.3	0.50 16.1	0.45 5.6	(6.5% of EI)[3]
Omega-6 (n-6) (g) (% of total meat fat)	0.17 3.95	0.44 14.2	0.28 3.50	(4% of EI)[5] Minimum ≥1% of EI from LA
Omega-3 (n-3) (g) (% of total meat fat)	0.07 1.63	0.05 1.61	0.16 2.0	450 mg/day of EPA+DHA[7] (0.5% of EI)[5] Minimum ≥0.2% of EI from ALA

Key: EI – energy intake; LA – linoleic acid; ALA – alpha linoleic acid; EPA – eicosapentaenoic acid; DHA – docosahexaenoic acid (where EPA and DHA are long-chain omega-3 polyunsaturated fatty acids (PUFAs))

Note: All figures provided are lean, raw, averages. Omega 3 recommendation = 450 mg/day (EPA/DHA).

Sources: [1]Food Composition, PHE (2021a)[4]: https://quadram.ac.uk/UKfoodcomposition/ (Beef; Lamb; Pork); [2]Nutrition & Health Claims, DHSC (2023)[5]; [3]Dietary Recommendations (DH 1991)[7]; [4] SACN (2019)[55]; [5] EFSA (2017)[57] **https://www.efsa.europa.eu/sites/default/files/2017_09_DRVs_summary_report.pdf**; SACN (2004)[58]

When looking at the percentage of total fat in beef, lamb and pork (Figure 6), lamb has higher long-chain omega-3 PUFA content, while pork is higher in omega-6 and polyunsaturated fat (omega-6 plus omega-3). Beef contains a higher proportion of monounsaturated fat and lamb has more saturated fat.

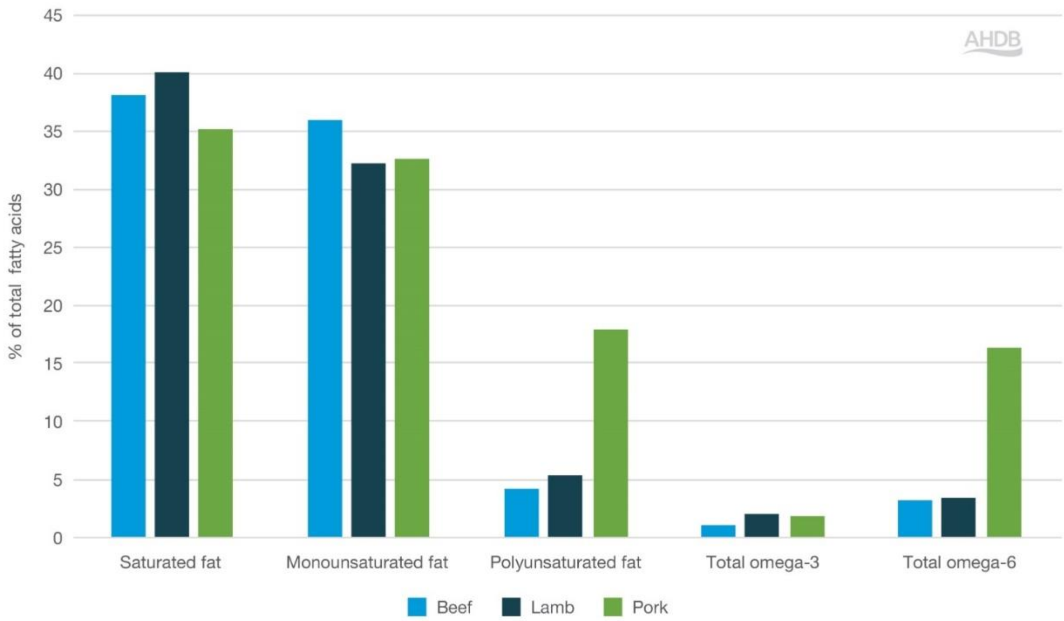


Figure 6. Percentage of total fat types for beef, lamb and pork

Source: Enser et al..[166]

Factors influencing the fatty acid composition of red meat

Animal feeding practices significantly impact the fatty acid profile of red meat. For instance, pasture-fed animals, such as Welsh lamb, show a more favourable profile, with grass-fed lambs exhibiting significantly higher long-chain omega-3 PUFAs and lower omega-6 PUFA levels compared with concentrate-fed lambs, achieving a low and optimal omega-6:omega-3 ratio of 1.0.[38]

Both root (brassica and grass) diets yield higher long-chain omega-3 PUFA concentrations compared with concentrate-based diets (i.e. straw, hay, oats, barley and silage), suggesting that root- and brassica-based diets could enhance omega-3 content as an alternative to grass feeding.[38] Additionally, grass-fed and root/brassica-fed lambs had higher iron levels, while grass-finished lambs showed increased levels of five essential amino acids levels. Previous studies on beef cattle also reported the nutritional benefits of grass-fed practices over intensive conventional and organic methods.[3] The same is true for pork,[56] suggesting that an animal's diet can improve the nutritional profile of red meat.

Dietary fats and health

From a health perspective, the type of fat consumed is more important than the amount, regarding prevention of cardiovascular disease (CVD), particularly coronary heart disease (CHD).[59] High saturated fat intake is associated with increased atherosclerotic CVD risk, leading to recommendations of less than 20 g/day (or <11% energy intake). The UK diet currently exceeds this (Table 11),[42] with average saturated fat intake ranging between 17.5–25.3 g/day across all age groups.[42] Reducing saturated fat can lower the CVD risk by decreasing low-density lipoprotein (LDL) cholesterol levels.[55]

Table 11. Current UK dietary fat recommendations and intake levels

Type of fat	Recommendations[1]	Current intakes[2]	
		Males	Females
Total fat	≤35% of energy intake (RI = 70 g/day)	34.4%	35.0%
Saturated fat	≤10% of energy intake (RI= 20 g/day)	12.3%	12.7%

Source: [1] DH (1991)[7] (Recommended figures based on % energy excluding alcohol) and SACN (2019).[55]

[2] NDNS data[42]

In contrast to saturated fats, unsaturated fats are considered beneficial for heart health, helping to reduce the risk of CVD and CHD.[60] Replacing saturated fats with unsaturated fatty acids, including long-chain polyunsaturated and monounsaturated fats, can lower cholesterol levels, associated with heart disease.[5] Long-chain omega-3 fatty acids EPA and DHA are beneficial in the prevention of strokes, heart attacks, hardening of the arteries and some cancers, as well as reducing the risk of inflammatory conditions.[59,61] Approved nutrition and health claims for DHA and EPA include maintaining normal blood pressure and blood triglyceride levels. DHA also contributes to normal brain function and visual development. Essential fatty acids are important for the normal growth and development of children. Replacing saturated fats with unsaturated fats reduces the risk of CHD.[5]

Long-chain omega-3 PUFAs EPA and DHA are low in the UK diet, with few rich food sources available (see further details on page 59). The Eatwell Guide recommends consuming two portions of fish per week, including at least one portion of oily fish (e.g. salmon, mackerel, sardines), which are rich in long-chain omega-3 PUFAs. However, some individuals may avoid fish due to sensory preferences related to taste, odour or texture (e.g. bones). Therefore, it is beneficial to obtain omega-3 from other sources. Although present in smaller quantities, the unsaturated fatty acids in red meat can help to enhance omega-3 intake.

Fat contribution of red meat in the UK diet

Secondary analysis of NDNS data from years 9–11 (2016/17–2018/19)[8] assessed the contribution of red *and* processed meat to fat intake among meat consumers. This analysis revealed that red and processed meat accounted for 9–11% of total fat and 9–13% of saturated fat intake in adults aged 19–65+ (Table 12).

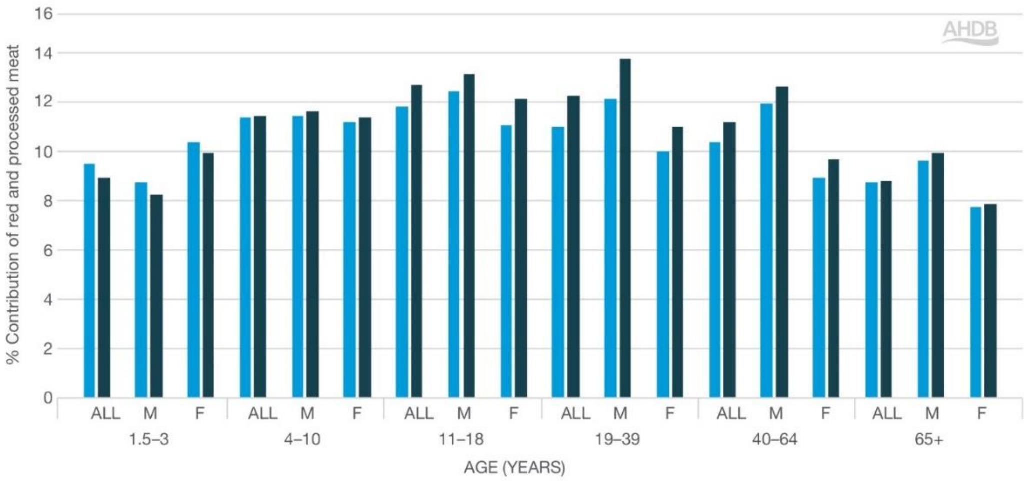
Table 12. Percentage contribution of red and processed meat to total and saturated fat intake

Nutrition	Age (years)					
	1.5–3	4–10	11–18	19–39	40–64	65+
Fat	10%	12%	12%	11%	11%	**9%**
Saturated fat	9%	12%	13%	13%	12%	**9%**

Source: BNF (2023a)[8]

Investigation of differences by gender identified that men aged 19–39 had the highest contribution to saturated fat intake at 13%, while women aged 65 and older had the lowest at 9% (Figure 7).

Figure 7. Contribution of red and processed meat to fat intakes by age and gender



Source: BNF (2023a) [8]

As the figures from the NDNS secondary analysis[8] represent both red and processed meat, the remaining section includes findings from the original NDNS (years 9–11, 2016/17–2018/19).[42]

Saturated fat in red meat compared to other foods

According to the NDNS,[42] average saturated fat intake is around 17–25 g/day, exceeding the adult reference intake (RI) of <20 g/day (<10% of energy intake) for all age groups over the age of four.[7]

To understand saturated fat sources in the UK diet, a comparison of food group contributions is necessary. While meat and meat products contribute less saturated fat than milk and milk products and cereals and cereal products, both of which contribute more saturated fat than meat and meat products, all three food groups contribute equally (21%) for adults aged 19 to 64 (Table 13).

When distinguishing red meat from other meat products, including processed meat, its contribution to saturated fat intake decreases substantially to 3–6%, compared with 9–17% for the latter. This makes its contribution comparable to that of vegetables and potatoes, both providing 6% for adults aged 19 to 64 (Table 13).

Additionally, red meat contributes a lower percentage of saturated fat than fat spreads and sugar, preserves and confectionery across all age groups. Other food groups contributing less saturated fat than red meat include everything except eggs and egg dishes (Table 13).

Table 13. Percentage contribution of different food groups to saturated fat intake, including meat and meat products

Food group	1.5–3 years (%)	4–10 years (%)	11–18 years (%)	19–64 years (%)	65–74 years (%)	75+ years (%)
Milk and milk products	45	28	21	21	24	26
Cereals and cereal products[1] (incl. processed)	20 (16)	28 (23)	27 (22)	21 (16)	18 (13)	21 (16)
Meat and meat products	**12**	**17**	**22**	**21**	**18**	**17**
Other meat[2] (incl. processed)[3]	9 (6)	13 (9)	17 (11)	16 (9)	12 (7)	10 (6)
Red meat[4]	3	4	5	6	6	6
Fat spreads[5]	8	9	9	10	14	17
Sugar, preserves and confectionery[6]	4	6	7	5	4	2
Vegetables and potatoes[7]	2	4	5	6	5	4
Eggs and egg dishes	2	2	2	5	5	4
Fish and fish dishes[8]	1	1	2	3	4	4
Miscellaneous	2	2	2	3	3	3
Savoury snacks	1	2	2	1	0	0
Nuts and seeds	1	1	0	2	2	1
Fruit	1	0	0	1	1	1
Avg. daily saturated fatty acids intake (g)	**17.5**	**21.1**	**23.6**	**25.3**	**24.2**	**25.2**

Source: NDNS[42]

Note: Total figure discrepancies are due to decimal place rounding off.

[1]Cereals and cereal products included pasta, rice, pizza and other miscellaneous cereals; white bread; wholemeal bread; brown, granary and wheatgerm bread; high-fibre breakfast cereals; other breakfast cereals; biscuits; buns, cakes, pastries and fruit pies; puddings. Processed versions include pasta, rice, pizza and other miscellaneous cereals; biscuits; buns, cakes, pastries and fruit pies; and puddings;

[2]Other meat included coated chicken and turkey; chicken, turkey and dishes; other meat, meat products and dishes;

[3]Processed meat included bacon and ham, burgers and kebabs, meat pies and pastries, and sausages;

[4]Red meat included beef, veal and dishes; lamb and dishes; pork and dishes;

[5]Fat spreads included butter, margarine and other fats and oils, reduced-fat spread – polyunsaturated and not polyunsaturated; low-fat spread – polyunsaturated and not polyunsaturated;

[6]Sugar preserves and confectionery included sugars, including table sugar, preservatives and sweet spreads; sugar confectionery; chocolate confectionery;

[7]Vegetables and potatoes included salad and other raw vegetables; vegetables (not raw) including vegetable dishes; chips, fried and roasted potatoes and potato products; other potatoes, potato salads and dishes;

[8]Fish and fish dishes included white fish coated or fried, including fish fingers; other white fish, shellfish or fish dishes and canned tuna; oily fish.

Further breakdown of the saturated fat contribution of the different types of meat is provided in Table 14 and Figure 8. For red meat, beef and veal contribute slightly more than lamb and pork. Overall, processed meats have higher saturated fat contributions than both red and other meat, with sausages significantly higher in younger age groups. Combined coated chicken, turkey and dishes contribute similar levels to red meat. Additionally, lamb and pork contribute less saturated fat than chicken and turkey sausages and meat pies and pastries, demonstrating that red meat has a significantly lower impact on saturated fat intake compared with processed meat.

Table 14. Contribution of meat and meat products to saturated fat intakes

Food group	Item	1.5–3 years (%)	4–10 years (%)	11–18 years (%)	19–64 years (%)	65–74 years (%)	75+ years (%)
Red meat	Beef, veal and dishes[1]	2	2	3	4	4	3
	Lamb and dishes[2]	0	1	1	1	1	2
	Pork and dishes[3]	0	1	1	1	1	1
	Red meat total	**(3)**	**(4)**	**(5)**	**(6)**	**(6)**	**(6)**
Processed meat	Bacon and ham[4]	1	1	2	2	2	2
	Burgers and kebabs [5]	0	1	2	1	0	0
	Meat pies and pastries[6]	2	2	3	3	3	3
	Sausages[7]	3	4	3	3	2	1
	Processed meat total	**(6)**	**(9)**	**(11)**	**(9)**	**(7)**	**(6)**
Other meat	Coated chicken and turkey[8]	1	1	2	1	0	0
	Chicken, turkey and dishes[9]	2	3	4	5	4	3
	Other meat, meat products and dishes[10]	0	1	1	1	1	1
	Other meat total	**(3)**	**(5)**	**(6)**	**(6)**	**(5)**	**(4)**
Total meat and meat product contribution		**(12)**	**(17)**	**(22)**	**(21)**	**(18)**	**(17)**

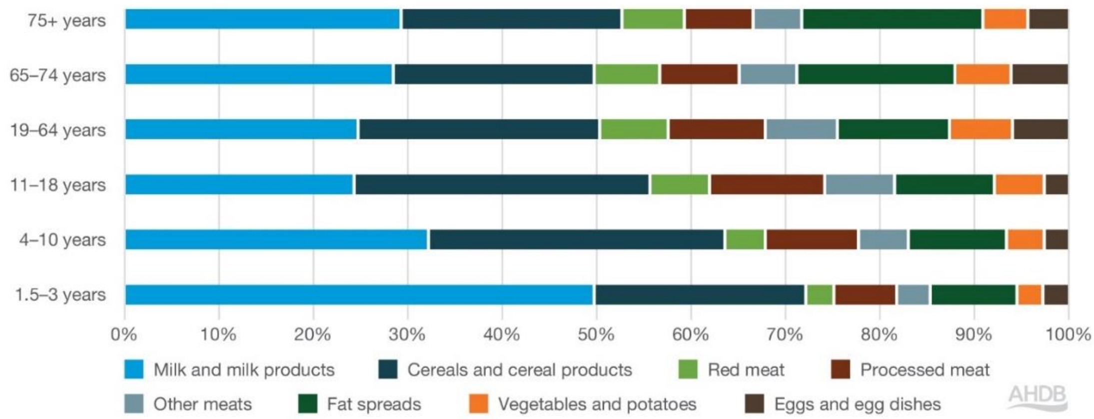
Source: NDNS[42] Note: Any total figure discrepancies () are due to decimal place rounding off from the original data.

[1]Beef, veal and dishes include manufactured beef products including ready meals – any types of beef and veal products purchased/retail, including ready meals, canned beef products and pastrami. Other beef and veal dishes include beef and veal joints, steaks, mince, cooked beef slices and home-made recipes, such as stews, casseroles, meatballs, lasagne, chilli, beef curry, Bolognese sauce, cottage pie, including beef takeaway dishes;

[2]Lamb and dishes include manufactured lamb products (including ready meals) – any types of lamb product purchased/retail, including ready meals and canned products. Other lamb (including home-made recipe dishes) includes lamb joints, chops, fillets and home-made recipes for Irish stew, shepherd's pie, lamb curries and casseroles. Includes lamb-based takeaway dishes;

[3]Pork and dishes include manufactured pork products (including ready meals) – any types of pork product (not ham or bacon) purchased/retail, including ready meals and canned pork products. Other pork (including home-made recipe dishes) includes pork joints, chops, steaks, belly rashers, crackling and home-made recipes for stews, casseroles, and sweet and sour pork. Includes pork-based takeaway dishes; Details of the other food groups can be found here **https://assets.publishing.service.gov.uk/media/5a7c7da5ed915d6969f453de/dh_128551.pdf**

Figure 8. Percentage contribution of selected food categories to saturated fat intake



Source: NDNS[42]

Red meat's contribution to omega-3 polyunsaturated fatty acids

A follow-up NDNS in 2020 assessed the impact of COVID-19 on diet and physical activity.[62] The results revealed low oily fish consumption across age groups:

- Children (11–18 years): 2 g/day (~14 g per week)
- Adults (19–64 years): 6 g/day (~42 g per week)
- Adults (65+ years): 11 g/day (~77 g per week)
    - All figures are well below the recommended weekly intake of 140 g of cooked oily fish to boost long-chain omega-3 PUFA intakes. Overall, the results highlight a decline in fish consumption over time, especially among older adults (aged 65+)
    - The European Food Safety Authority (EFSA) recommends an intake of 250 mg of EPA and DHA per day,[63] while SACN recommends 450 mg.[58] Given the decline in fish consumption and potential depletion of fish stocks, alongside estimated population growth, it is predicted that fish alone will not meet the demand for long-chain omega-3 PUFA intakes.[64] Therefore, exploring alternative sources of omega-3 PUFAs is crucial, as few foods provide an adequate source of this essential nutrient. A holistic whole-diet approach is needed to improve omega-3 intakes
    - NDNS data suggests that the average omega-3 PUFA intake is 2.1 g/day for adults aged 19–64, with men averaging 2.3 g and women 1.9 g.[42] However, it is unclear how much of this includes long-chain EPA and DHA from animal sources versus short-chain essential fatty acid alpha linolenic acid (ALA) from plants. Meat and meat products contribute more omega-3 than fish, with red meat (beef, lamb and pork) providing roughly half that of oily fish for adults aged 19–64 (Table 15),[42] possibly due to declining fish consumption.[62] Among red meats, beef and veal contribute more omega-3 than lamb and pork from the age of 11.
    - Grass-fed beef can significantly enhance omega-3 intake, containing up to five times more omega-3 PUFAs than grain-fed beef.[65] A recent study demonstrated that consuming 70 g/day of grass-fed beef could meet 66% of the recommended UK intake of omega-3 PUFA.[3] Grass-fed beef is therefore a particularly valuable source of omega-3 and incorporating it into diets where fish consumption is low could help compensate for the decline in omega-3 intake

Table 15. Percentage contribution of meat and fish to omega-3 intakes

Percentage contribution to omega- 3 PUFA	1.5–3 years (%)	4–10 years (%)	11–18 years (%)	19–64 years (%)	65–74 years (%)	75+ years (%)
Meat and meat products	**15**	**17**	**23**	**18**	**14**	**13**
of which: Lamb and dishes[2]	1	1	2	2	2	2
Beef, veal and dishes[1]	1	1	1	1	1	1
Pork and dishes[3]	0	1	1	1	1	1
Total red meat	**2%**	**3%**	**4%**	**4%**	**4%**	**4%**
Fish and fish dishes	**9**	**8**	**7**	**13**	**20**	**18**
Of which: Other white fish, shellfish or fish dishes and canned tuna	1	1	2	3	3	2
Oily fish	4	4	3	9	15	14
Total white and oily fish	**5%**	**5%**	**5%**	**12%**	**18%**	**16%**

Note: PUFA: polyunsaturated fatty acids

[1]Beef, veal and dishes include manufactured beef products, including ready meals – any types of beef and veal products purchased/retail, including ready meals, canned beef products and pastrami. Other beef and veal dishes include beef and veal joints, steaks, mince, cooked beef slices and home-made recipes, such as stews, casseroles, meatballs, lasagne, chilli, beef curry, Bolognese sauce, cottage pie, including beef takeaway dishes;

[2]Lamb and dishes include manufactured lamb products (including ready meals) – any types of lamb product purchased/retail, including ready meals and canned products. Other lamb (including home-made recipe dishes) includes lamb joints, chops, fillets and home-made recipes for Irish stew, shepherd's pie, lamb curries and casseroles. Includes lamb-based takeaway dishes;

[3]Pork and dishes include manufactured pork products (including ready meals) – any types of pork product (not ham or bacon) purchased/retail including ready meals and canned pork products. Other pork (including home-made recipe dishes) includes pork joints, chops, steaks, belly rashers, crackling and home-made recipes for stews, casseroles and sweet and sour pork. Includes pork-based takeaway dishes.

Micronutrients in red meat

Red meat provides 11 vitamins and minerals that qualify for 'source of' or 'high in' through the GB nutrition and health claims,[5] as shown in Table 16 for beef, lamb and pork. These claims align with European Union standards. To qualify as a source of a vitamin or mineral, a food must contain a significant amount, as defined in the Annex to the retained Directive 90/496/EEC, or an amount provided for by derogations granted according to Article 6 of the retained Regulation (EC) No. 1925/2006 of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to foods.

Table 16. Nutritional contribution of different red meats, highlighting those that provide a valuable source of micronutrients

Micronutrient		Beef (100 g raw, lean)		Lamb (100 g raw, lean)		Pork (100 g raw, lean)	
		Source of	High-in	Source of	High-in	Source of	High-in
Protein	-	No	yes	No	No	No	yes
Vitamins	Thiamine	No	No	No	No	No	yes
	Riboflavin	yes	No	No	No	No	No
	Niacin	No	yes	No	No	No	yes
	Vitamin B6	No	yes	yes	yes	yes	No
	Vitamin B12	No	yes	No	No	yes	No
	Pantothenic acid	No	No	yes	yes	yes	No
Minerals	Potassium	yes	No	yes	No	yes	No
	Phosphorous	yes	No	yes	No	No	yes
	Iron	yes	No	No	No	No	No
	Zinc	No	yes	No	yes	yes	No
	Selenium	No	No	No	No	No	yes

Note: 'Source of' and 'high in' criteria for each micronutrient as defined within DHSC (2023).[5]

A food can claim to be 'a source of' vitamins and minerals only if it contains at least 15% of the nutrient reference value (NRV).[5] To claim to be 'high in' or 'a rich source ', a vitamin or mineral must contain at least 30% of the NRV.[5] Nutrition and health claims imply that the food has beneficial nutritional attributes, such as providing a 'source of vitamin B12', accompanied by a defined health relationship, for example, 'red blood cell formation'.[5,66] Tables 20 and 21 list the key nutrients present in beef, lamb and pork, as well as the associated health relationship and applicable health claims that can be made.

Table 17. Vitamins in red meat: Nutrition claims, health benefits and health claims

Nutrient	Claim	Health relationship	Beef		Lamb		Pork	
			Source	Rich	Source	Rich	Source	Rich
Thiamine (vitamin B1)	Thiamine contributes to normal energy-yielding metabolism	Energy-yielding metabolism						yes
	Thiamine contributes to normal functioning of the nervous system	Function of the nervous system						
	Thiamine contributes to normal psychological function	Contribution to normal psychological functions						
	Thiamine contributes to the normal function of the heart	Cardiac function						
Riboflavin (vitamin B2)	Riboflavin contributes to normal energy-yielding metabolism	Contribution to normal energy-yielding metabolism	yes				yes	
	Riboflavin contributes to normal functioning of the nervous system	Maintenance of the normal function of the nervous system						
	Riboflavin contributes to the maintenance of normal mucous membranes	Maintenance of normal skin and mucous membranes						
	Riboflavin contributes to the maintenance of normal red blood cells	Maintenance of normal red blood cells						
	Riboflavin contributes to the maintenance of normal skin	Maintenance of normal skin and mucous membranes						
	Riboflavin contributes to the maintenance of normal vision	Maintenance of normal vision						
	Riboflavin contributes to the normal metabolism of iron	Contribution to normal metabolism of iron						

	Riboflavin contributes to the protection of cells from oxidative stress	Protection of DNA, proteins and lipids from oxidative damage						
	Riboflavin contributes to the reduction of tiredness and fatigue	Reduction of tiredness and fatigue						
Niacin (vitamin B3)	Niacin contributes to normal energy-yielding metabolism	Contribution to normal energy-yielding metabolism		yes		yes		yes
	Niacin contributes to normal functioning of the nervous system	Function of the nervous system						
	Niacin contributes to normal psychological function	Contribution to normal psychological functions						
	Niacin contributes to the maintenance of normal mucous membranes	Maintenance of normal skin and mucous membranes						
	Niacin contributes to the maintenance of normal skin	Maintenance of normal skin and mucous membranes						
	Niacin contributes to the reduction of tiredness and fatigue	Reduction of tiredness and fatigue						
Pantothenic Acid (vitamin B5)	Pantothenic acid contributes to normal energy-yielding metabolism	Energy-yielding metabolism			yes		yes	
	Pantothenic acid contributes to normal mental performance	Mental performance						
	Pantothenic acid contributes to normal synthesis and metabolism of steroid hormones, vitamin D and some neurotransmitters	Synthesis and metabolism of steroid hormones, vitamin D and some neurotransmitters						
	Pantothenic acid contributes to the reduction of tiredness and fatigue	Reduction of tiredness and fatigue						
Vitamin B6	Vitamin B6 contributes to normal cysteine synthesis	Contribution to normal cysteine synthesis		yes	yes		yes	

	Vitamin B6 contributes to normal energy-yielding metabolism	Contribution to normal energy-yielding metabolism						
	Vitamin B6 contributes to normal functioning of the nervous system	Function of the nervous system						
	Vitamin B6 contributes to normal homocysteine metabolism	Contribution to normal homocysteine metabolism						
	Vitamin B6 contributes to normal protein and glycogen metabolism	Protein and glycogen metabolism						
	Vitamin B6 contributes to normal psychological function	Contribution to normal psychological functions						
	Vitamin B6 contributes to normal red blood cell formation	Red blood cell formation						
	Vitamin B6 contributes to the normal function of the immune system	Function of the immune system						
	Vitamin B6 contributes to the reduction of tiredness and fatigue	Reduction of tiredness and fatigue						
	Vitamin B6 contributes to the regulation of hormonal activity	Regulation of hormonal activity						
	Vitamin B12 contributes to normal energy-yielding metabolism	Energy-yielding metabolism		yes		yes	yes	
	Vitamin B12 contributes to normal functioning of the nervous system	Contribution to neurological and psychological function						
	Vitamin B12 contributes to normal homocysteine metabolism	Contribution to normal homocysteine metabolism						
	Vitamin B12 contributes to normal psychological function	Contribution to neurological and psychological function						
	Vitamin B12 contributes to normal red blood cell formation	Red blood cell formation						

	Vitamin B12 contributes to the normal function of the immune system	Function of the immune system						
	Vitamin B12 contributes to the reduction of tiredness and fatigue	Reduction of tiredness and fatigue						
	Vitamin B12 has a role in the process of cell division	cell division						

Key: ‘High in’ also refers to being a ‘rich source’ of the micronutrient concerned

Source: [1]DHSC (2023)[5]; [2]PHE (2021a)[4]

Table 18. Minerals in red meat: Nutrition claims, health benefits and health claims

Nutrient	Claim	Health relationship	Beef		Lamb		Pork	
			Source	Rich	Source	Rich	Source	Rich
Potassium	Potassium contributes to normal functioning of the nervous system	Muscular and neurological function	yes		yes		yes	
	Potassium contributes to normal muscle function	Muscular and neurological function						
	Potassium contributes to the maintenance of normal blood pressure	Blood pressure						
Phosphorus	Phosphorus contributes to normal energy-yielding metabolism	Energy-yielding metabolism	yes		yes			yes
	Phosphorus contributes to normal function of cell membranes	Function of cell membranes						
	Phosphorus contributes to the maintenance of normal bones	Maintenance of bone and teeth						
	Phosphorus contributes to the maintenance of normal teeth	Maintenance of bone and teeth						
	Phosphorus is needed for the normal growth and development of bone in children	Normal growth and development of bone in children						
Iron	Iron contributes to normal cognitive function	Cognitive function	yes					
	Iron contributes to normal energy-yielding metabolism	Contribution to normal energy-yielding metabolism						
	Iron contributes to normal formation of red blood cells and haemoglobin	Formation of red blood cells and haemoglobin						
	Iron contributes to normal oxygen transport in the body	Oxygen transport						
	Iron contributes to the normal function of the immune system	Function of the immune system						

	Iron contributes to the reduction of tiredness and fatigue	Reduction of tiredness and fatigue						
	Iron has a role in the process of cell division	Cell division						
	Meat or fish contributes to the improvement of iron absorption when eaten with other foods containing iron	Improvement of non-haem iron absorption						
	Iron contributes to normal cognitive development of children	Normal cognitive function in children		yes		yes	yes	
	Zinc contributes to normal DNA synthesis	DNA synthesis and cell division						
	Zinc contributes to normal acid-base metabolism	Acid-base metabolism						
	Zinc contributes to normal carbohydrate metabolism	Contribution to normal carbohydrate metabolism						
	Zinc contributes to normal cognitive function	Cognitive function						
	Zinc contributes to normal fertility and reproduction	Fertility and reproduction						
Zinc	Zinc contributes to normal macronutrient metabolism	Contribution to normal macronutrient metabolism						
	Zinc contributes to normal metabolism of fatty acids	Maintenance of normal serum testosterone concentrations						
	Zinc contributes to normal metabolism of vitamin A	Vitamin A metabolism						
	Zinc contributes to normal protein synthesis	Contribution to normal protein synthesis						
	Zinc contributes to the maintenance of normal bones	Maintenance of bones						
	Zinc contributes to the maintenance of normal hair	Maintenance of normal hair						
	Zinc contributes to the maintenance of normal nails	Maintenance of normal nails						
	Zinc contributes to the maintenance of normal skin	Maintenance of normal skin						

	Zinc contributes to the maintenance of normal testosterone levels in the blood	Fertility and reproduction						
	Zinc contributes to the maintenance of normal vision	Maintenance of vision						
	Zinc contributes to the normal function of the immune system	Function of the immune system						
	Zinc contributes to the protection of cells from oxidative stress	Protection of DNA, proteins and lipids from oxidative damage						
	Zinc has a role in the process of cell division	DNA synthesis and cell division						
Selenium	Selenium contributes to normal spermatogenesis	Spermatogenesis						yes
	Selenium contributes to the maintenance of normal hair	Maintenance of normal hair						
	Selenium contributes to the maintenance of normal nails	Maintenance of normal nails						
	Selenium contributes to the normal function of the immune system	Maintenance of the normal function of the immune system						
	Selenium contributes to the normal thyroid function	Thyroid function						
	Selenium contributes to the protection of cells from oxidative stress	Protection of DNA, proteins and lipids from oxidative damage						

Key: ‘High in’ also refers to being a ‘rich source’ of the micronutrient concerned
Source: [1]DHSC (2023)[5]; [2]PHE (2021a)[4]

Dietary or nutrient reference values (NRVs) indicate nutrient amounts to meet a defined population group's requirement. This includes the reference nutrient intake (RNI), which meets the needs of 97.5% of the population; estimated average requirements (EAR), which satisfy 50%; and the lower reference nutrient intake (LRNI), which meets only 2.5% of the population's needs.[7] Food labelling uses reference intake (RI) for daily nutrient needs. NRVs for vitamins and minerals help determine if a food can claim to be a source of or is high or rich in a specific nutrient. Table 19 provides LRNI data for selected nutrients from the NDNS (years 9–11, 2016/17–2018/19), while Table 20 and Figure 9 summarise threshold levels for nutrient inadequacy or deficiency measured by blood markers.[42]

Table 19. Percentage of lower reference nutrient intakes (LRNI) by age for selected micronutrients in meat.

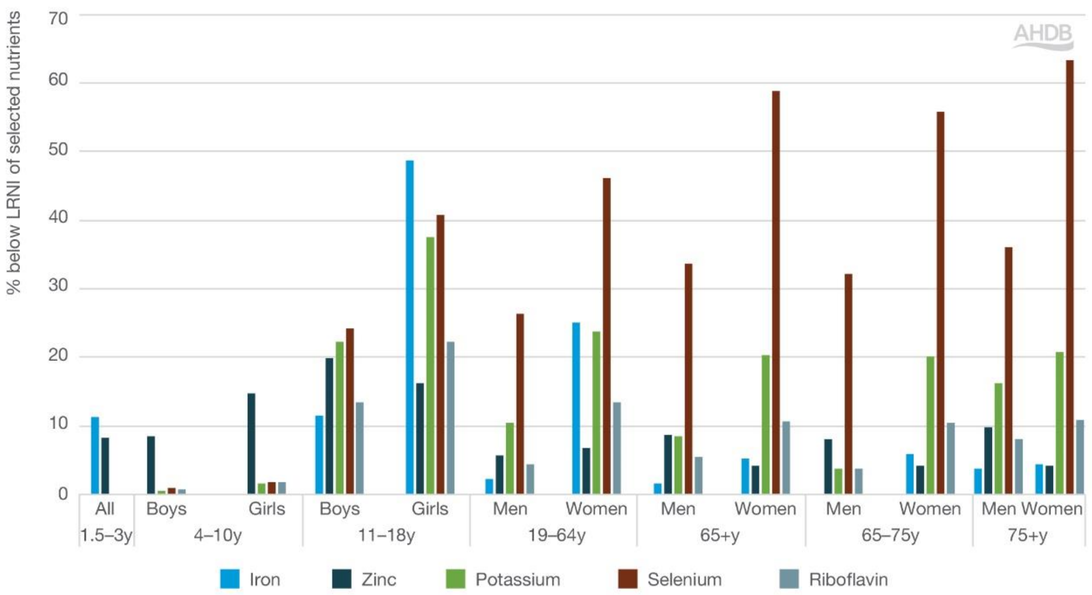
Micronutrient	1.5-3 y	4–10 y		11–18 y		19–64 y		65+ y		65–74 y		75+ y	
	All	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Riboflavin	0	1	2	13#	22#	4	13#	5*	10#	4	10#	8*	11#
Iron	11#	1	2	11#	49#	2	25#	1	5*	0	6*	4	4
Zinc	8*	8*	15#	20#	16#	6*	7*	9*	4	8*	4	10#	4
Potassium	0	0	1	22#	37#	10#	24#	8*	20#	4	20#	16#	21#
Selenium	0	1	2	24#	41#	26#	46#	34#	59#	32#	56#	36#	63#

Note: The lower reference nutrient intake (LRNI) is the amount considered sufficient for only 2.5% of the population with the lowest physiological requirements, where most people will need more. Intakes below this level could lead to an increased risk of deficiency.

Key: Dark blue shading or # – >10% of the LRNI; light blue shading or * –between 5 and 10% of the LRNI

Source: NDNS (Years 9–11, 2016/17 to 2018/19)[42]

Figure 9. Percentage of the population with intakes below the LRNI for selected nutrients



Note: The lower reference nutrient intake (LRNI) is the amount considered sufficient for only 2.5% of the population with the lowest physiological requirements, where most people will need more. Intakes below this level could lead to an increased risk of deficiency.

Source: NDNS (years 9–11, 2016/17 to 2018/19)[42]

Table 20. Prevalence of below-threshold levels indicating inadequate status or deficiency for selected micronutrients relevant to red meat consumption

Age and gender	Haemoglobin Iron status[1] (%)	Plasma ferritin iron status[2] (%)	Iron deficiency[3] (%)	Vitamin B12 deficiency[4] (%)	Vitamin D deficiency[5] (%)	Vitamin D status[6] (nmol/L)
Children 4–10 years	5	9	0	5	2	60
Boys	6	5	0	5	1	63
Girls	4	13	0	[5]	3	57
Children 11–18 years	5	11	5	7	19	44
Boys	1	6	1	11	21	45
Girls	9	17	9	3	17	42
Adults 19–64 years	5	8	3	7	16	48
Men	3	1	0	5	18	45
Women	7	15	5	10	15	51
Adults 65+ years	13	2	1	6	13	57
Men	15	0	0	7	13	53
Women	11	3	2	5	13	56

Source: NDNS (years 9–11, 2016/17 to 2018/19)[42]

Note: Iron: [1]Haemoglobin – percentage below age and sex thresholds: 1.5–4y males <110 g/L, 1.5–4y females <110 g/L, 5–11y males <115 g/L, 5–11y females <115 g/L, 12–14y males <120 g/L, 12–14y females <120 g/L, 15y+ males <130 g/L, 15y+ females (non-pregnant) <120 g/L;

[2]Plasma ferritin – percentage below age and sex thresholds: 1.5–4y males <12 mg/L, 1.5–4y females <12 mg/L, 5y+ males <15 mg/L, 5y+ females <15 mg/L;

[3]Haemoglobin and plasma ferritin concentrations below the World Health Organization (WHO) age/sex-dependent thresholds for iron deficiency and anaemia;

Vitamin B12: [4]Holotranscobalamin (HoloTC) <32 pmol/L. Holotranscobalamin (HoloTC) is the active form of vitamin B12; <32 pmol/L indicates a biochemical deficiency, the concentration below which urinary methylmalonic acid is likely to be raised. Annals of Clinical Biochemistry. 2012. (49) 184–189;

[ ] denotes a sample size <50, which may not be representative of the population;

Vitamin D: [5]Mean 25-hydroxyvitamin D status below 25 nmol/L, indicating increased risk of deficiency. [6]Mean 25-hydroxyvitamin D (25-OHD) concentration (nmol/L).

Vitamins

An overview of the different B-vitamins found in red meat, and their accompanying health relationship and claims is highlighted in Table 17.

The B-vitamins

Red meat provides a variety of B-vitamins; beef provides 'a rich source' of vitamin B6 and is also 'high in' vitamin B12, along with lamb. All three meats (beef, lamb and pork) are 'rich sources' of niacin (vitamin B3) (Table 21).

Pork is 'high in' thiamine (vitamin B1), while beef and lamb provide a 'source of' riboflavin (vitamin B2) and both lamb and pork provide offer a 'source of' pantothenic acid (vitamin B5).

Table 21. Selected vitamins in red meat – beef, lamb and pork (per 100 g)

Red meat per 100 g	Vitamin D (µg)	Thiamine (B1) (mg)	Riboflavin (B2) (mg)	Niacin (B3) (mg)	Vitamin B6 (mg)	Vitamin B12 (µg)	Pantothenic Acid (B5) (mg)
NRV	5	1.1	1.4	16	1.4	2.5	6
High in	**1.5***	**0.33***	**0.42***	**4.8***	**0.42***	**0.75***	**1.8***
Source of	**0.75#**	**0.165#**	**0.21#**	**2.4#**	**0.21#**	**0.375#**	**0.9#**
Beef	0.5	0.1	**0.21#**	**9.7***	**0.53***	**2***	0.75
Lamb	0.4	0.09	0.20	**9.3***	**0.3#**	**2***	**0.92#**
Pork	0.4	**0.71***	0.19	**13.4***	**0.38#**	**0.5#**	**1.05#**

Key: NRV – nutrient reference value. The NRV for vitamin D is 5 µg. This differs from the UK recommendation to consume 10 µg per day. Before leaving the EU, food labelling regulations were harmonised at the EU level. Since leaving the EU, these regulations have been retained under EU law and form part of domestic food law in Great Britain. The retained EU NRV for vitamin D is 5 µg/day, compared with the UK recommendation of 10 µg/day. All figures provided are lean, raw averages. Niacin is expressed as niacin equivalents.

Shading used – dark blue or * denotes a 'high in/rich source of' the vitamin; lighter blue or # denotes a 'source of' the vitamin.

Source: https://quadram.ac.uk/Ukfoodcomposition/ (Beef; Lamb; Pork)

Role of B-vitamins in health

B vitamins are essential for a myriad of health functions (Table 17). They have an important role to play in energy production, reduction in tiredness and fatigue (except B1), nervous system function and psychological (B1, B3, B6 and B12) and neurological function (B12) or mental performance (B5). They also contribute to red blood cell formation (B2, B6 and B12), homocysteine metabolism (B6 and B12), heart function (B1), immune function (B6 and B12), hormone and neurotransmitters synthesis (B5) and the maintenance of skin and mucous membranes (B2 and B3). Additionally, they support iron metabolism, oxidative stress protection, vision (B2), cell division (B12), cysteine synthesis and protein and glycogen metabolism (B6).[5] Table 21 highlights the contribution of various red meats to B vitamins, emphasising whether they are a source of or rich in particularly for niacin, pantothenic acid (B5), B6 and B12.

B-vitamin deficiency – a potential cause of concern within the UK?

NHS admissions data shows a four-fold increase in B-vitamin deficiencies from 2013/14 to 2022/23, rising from under 30,000 in 2013/14 to over 120,000 in 2022/23 (see Table 25).[67] In 2022/23, there were 1,963 admissions for thiamine deficiency and 22 for niacin deficiency (pellagra). The reasons for this significant increase are unclear, but low adherence to current dietary recommendations and overall diet quality are likely factors.

Vitamin B12

Vitamin B12 is crucial for energy, nervous system and psychological function, immunity, normal red blood cell formation, homocysteine metabolism and cell division (Table 17).[5]

Vitamin B12 intakes, status and risk of deficiency

The RNI (amount to meet 97.5% of the population's requirements) for vitamin B12 is 1.5 µg/day for men and women aged 15–50+, increasing to 2 µg/day during breastfeeding (+0.5 µg/day). For adolescents aged 11–14, it is 1.2 µg/day. The LRNI (which meets only 2.5% of population requirements) for vitamin B12 is 1.0 µg.[7] Although we do not have data from the most recent NDNS,[42] an analysis of the NDNS data by the Scientific Advisory Committee on Nutrition (SACN)[68] showed an average intake of 5.1 µg/day in adults aged 19–64, with 0–3% of adults 19–80+ failing to meet the LRNI.

An additional report by Food Standards Scotland (FSS) that examined the impact of reductions in meat and dairy on nutrient intake and disease risk using data from the Scottish Health Survey (SHeS)[69] showed that average vitamin B12 intakes were 4.8 µg/day for men and 3.8 µg/day for women aged 19–50, where 0–14% of Scottish adults did not meet the RNI (1.5 µg/day), which was highest in women aged 35–44 (14%) and lowest in men aged 75+ (0%) (FSS 2024). Essentially, more than 1 in 10 Scottish women aged 16–54 had vitamin B12 intake below the RNI (11–14%), which was similar to men aged 25–34 (13%), while, in contrast, this was particularly lower in the remaining male age groups, where only 3–6% had intake below the RNI.

The current NDNS[42] does not provide any details related to LRNI for vitamin B12 throughout the age spectrum.[42] However, blood markers indicate that 5–7% of children aged 4–10 are deficient, with 11% of 11–18-year-old boys and 3% of girls also affected (Table 23). This suggests poorer vitamin intake in boys. Among adults, 7% of those aged 19–64 and 6% of those 65+ are deficient. Women (19–64) experience twice the level of deficiency (10%) compared with men (5%) (Table 20). Annual NHS admissions data indicates that 19,000–25,000 patients are diagnosed with vitamin B12 deficiency anaemia, with 24,694 patients diagnosed in 2022–23.[67] Specific age, sex and dietary intake patterns related to these figures are unclear.

Implications of vitamin B12 deficiency

Vitamin B12 deficiency can lead to various symptoms that typically develop gradually and worsen without treatment. Comon symptoms include shortness of breath, headaches, loss of appetite, palpitations, vision problems, fatigue, a sore or red tongue and cognitive changes, such as memory and understanding problems. In severe cases scenarios, it may also cause neurological symptoms such as numbness, muscle weakness, psychological problems and issues with balance and coordination.[70]

Food category contributions, including red meat to vitamin B12 intakes

The current NDNS report does not provide details on the contribution of different food categories to vitamin B12 intakes.[42] This has not been the case since years 1–4 (2008–2012) were published.[71] However, secondary analysis indicates that red and processed meat accounts for 18% of dietary B12 intake among children aged 11–18 – the highest among the age groups – followed by 17% of adults aged 19–39 and 16% in those aged 40–64.[8]

Data from the Scottish Health Survey (SHeS) (2021),[69] taken from the recent FSS report,[72] reveals that milk and milk products contribute the most to vitamin B12 intake (36%), followed by meat and meat products (12%), cereals and cereal products (11%), fish and fish dishes (10.3%) and egg and egg dishes (9.4%). Red meat, specifically beef and lamb, is a rich source of vitamin B12, while pork is a source (Table 21).[5] Animal-derived foods are the only natural sources of vitamin B12, crucial for a healthy balanced diet.[10] Notably, considering the SHeS data above, apart from cereal-based products, the food categories mentioned are absent from the diets of vegetarians and vegans, collectively providing 75% of the vitamin B12 intake from food.[72]

Those embarking on plant-based or vegan diets are at higher risk of vitamin B12 deficiency, making it crucial to communicate the essential need for vitamin B12 supplementation and consumption of fortified foods. While fortifying staple foods is important, it cannot replicate the benefits of whole, minimally processed, nutritionally dense foods which offer additional nutrients and bioactive compounds.[73] The British Dietetic Association (BDA) recommends a vitamin B12 supplement of at least 10 µg/day for vegetarians and vegans.[74] A new NDNS report including vitamin B12 data is expected in 2025.

Vitamin D

Vitamin D supports several health functions, including muscle maintenance and function, dental health and optimal bone growth and development in children. It also plays a role in cell division and immune system function.[5] For more details on vitamin D roles in health, refer to the SACN Vitamin D and Health report.[75]

Vitamin D intakes, status and risk of deficiency

The average vitamin D intake is 2.9 µg/day for adults aged 19–64, rising to 3.2 µg/day for those aged 65–74 and 3.3 µg/day for 75+.[42] In children (ages 1.5–18), daily intake is lower – at 2.2–2.4 µg. With an RNI of 10 µg/day for vitamin D, the UK faces concerns about inadequate vitamin D intake, particularly during winter months when sunlight exposure is limited. This is because vitamin D is not only obtained from the few foods rich in the nutrient but also naturally synthesised from cholesterol in the body's skin following exposure to sunlight.[75]

Looking at blood markers of vitamin D status, NDNS data shows that 19% of children aged 11–18 have low vitamin D levels (<25 nmol/L) and are at increased risk of deficiency (Table 20).[42] In adults aged 19–64, average vitamin D concentrations are 48 nmol/L, while older adults (65+) average 57 nmol/L and children aged 4–10 have 60 nmol/L. Teenagers (11–18 years) have lower vitamin D levels at 44 nmol/L, with similar values across genders in each age group (Table 20).[42]

Analysis of NHS hospital admissions data to investigate vitamin D deficiency rates reveals a fivefold increase over the past decade, with 188,114 cases in 2022–23 data, compared with only 31,576 in 2013–14 (Table 25).[67]

This rise may be potentially attributed to the changing ethnic mix of the UK population and increased testing awareness within UK hospitals. Interestingly, active rickets cases (bone development abnormalities) in children have remained steady, with 498 cases in 2013–14 and 482 cases in 2022–23.

Implications of vitamin D deficiency

Low vitamin D intake can impair bone growth and development, leading to weakened bones, rickets in children and osteomalacia in adults.[75]

Food category contributions, including red meat to vitamin D intakes

Meat and eggs and their products make up the largest contribution to vitamin D intake in adults aged 19 to 64, accounting for 25% and 22% of their dietary intake, respectively.[42] Fish and fish dishes make up 17% (13% from oily fish), whereas fortified cereals and cereal products make up 16%. The contribution to vitamin D intake from red meat alone in adults aged 19–64 is 8%, with beef and veal dishes being the highest red meat contributors at 5%.

Similarly, in teenagers (11–18), meat and meat products make the highest contribution to dietary vitamin D intake at 29%, with an almost identical contribution from cereals and cereal products at 28%. Interestingly, in adolescents, fish and fish products contribute substantially less vitamin D at 8% (5% from oily fish) compared with adults.[42] The red meat contribution to vitamin D in adolescents is 9% of dietary intake, with 5% from beef.

In younger children, the picture is slightly different. Most dietary vitamin D comes from milk and milk products, making up 30% in children aged 1.5–3 but falls to 17% in those aged 4–10. Meat and meat products provide 14% of vitamin D in 1.5–3-year-olds but increases to 19% in 4–10-year-olds, where 3% of that comes from red meat in both age groups. Interestingly, fish and fish products provide greater dietary vitamin D than red meat, at 6–7% (4–5% from oily fish) for 1.5–3-year-olds and 4–11-year-olds, respectively.[42]

In older adults (65–74 and 75+ years old), the contribution of meat and meat products to dietary vitamin D compared with adults (19–64) is slightly lower, at 20 and 22%, but the contribution of fish and fish dishes is slightly higher at 23–24% (19–20% from oily fish), respectively.

Overall, the NDNS data highlights the key contribution meat and meat products currently make towards dietary intake of vitamin D, for both teenagers and adults. As a result, recommendations to eat less meat may need to consider the possible impact on vitamin D intakes in the UK. Although red meat consumption does not quite qualify as a source of vitamin D (0.75 µg/100 g), raw lean beef provides 0.5 µg/100 g, whereas lamb and pork provide 0.4 µg/100 g of vitamin D (Table 21).[5] Therefore, red meat consumption makes a significant contribution to vitamin D intake, providing 4–5% of requirements in children and 8–9% in teenagers and adults (18+). Beef is the predominant provider of vitamin D at 5–6%, but pork is also a key contributor for teenagers at 3%. Recent research suggests that pork vitamin D levels can be increased through greater sun exposure in outdoor rearing practices[76] or artificially via indoor exposure to ultraviolet radiation (UVB).[77] Leveraging such farming practices can further enhance the dietary contribution of red meat to vitamin D.

Minerals

All the different minerals found in red meat, along with their health benefits and nutrition claims, are presented in Table 18. Beef, lamb and pork all qualify as a source of potassium, phosphorus and zinc. Beef and lamb are rich in zinc, whereas pork is rich in phosphorus. Additionally, pork is rich in selenium, while beef is a source of iron (Table 22).

Table 22. Comparison of the key minerals found in beef, lamb and pork (per 100 g) according to UK Food Composition Data

Red meat per 100 g	Potassium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)	Selenium (µg)
NRV	2,000	700	14.8	10	55
High in	**600***	**210***	**4.2***	**3***	**16.5***
Source of	**300#**	**105#**	**2.1#**	**1.5#**	**8.25#**
Beef	**350#**	**200#**	**2.7#**	**4.1***	7
Lamb	**330#**	**190#**	1.4	**3.3***	4
Pork	**387#**	**211***	0.75	**2.1#**	**18***

Key**:** NRV – nutrient reference value. *All figures provided are lean, raw averages. Shading used – dark blue or * denotes a 'rich source' of the vitamin; the lighter blue or # denotes a 'source of' the vitamin.

Source: https://quadram.ac.uk/Ukfoodcomposition/ (Beef; Lamb; Pork)

Iron

Iron supports energy metabolism, reduces fatigue, enhances immune function and aids cognitive function in adults and development in children. It also facilitates cell division, oxygen transport, red blood cell and haemoglobin formation (Table 18).[5] For more details on iron's dietary importance, refer to the SACN report Iron and Health.[78]

Iron Intakes, status and risk of deficiency

The RNI and LRNI for iron varies by age and gender needs (Table 23). The NDNS[42] reports an average daily iron intake of 10.5 mg/day for adults aged 19–64, meeting the RNI for men aged 19–50 and women over 50 (8.7 mg/day). However, it falls short for women aged 19–50 (14.8 mg/day), who lose large stores of iron due to menstruation (Table 23).

Table 23. Reference nutrient intakes for iron

Population group	Age	LRNI (mg of Iron/day)	RNI (mg of Iron/day)
Infants and children	0–3 months	-	1.7
	4–6 months	-	4.3
	7–9 months	-	7.8
	10–12 months	-	7.8
	1–3 years	3.7	6.9
	4–6 years	3.3	6.1
	7–10 years	4.7	8.7
Males	11–14 years	6.1	11.3
	15–18 years	6.1	11.3
	19–50 years	4.7	8.7
	50+ years	4.7	8.7
Females	11–14 years	8.0	14.8*
	15–18 years	8.0	14.8*
	19–50 years	8.0	14.8*
	50+ years	4.7	8.7

Key: LRNI – lower reference nutrient intake is the amount considered sufficient for only 2.5% of the population with the lowest physiological requirements, where most people will need more. Intakes below this level could lead to an increased risk of deficiency;

Notes: RNI – reference nutrient intake is the amount of a nutrient that is enough to ensure that the needs of nearly all the group (97.5%) are being met. For women with high menstrual losses, this amount is considered insufficient, meaning that consumption of iron intake can help meet requirements.

* denotes that the data excludes those with high menstrual losses whose iron intakes should be increased further

Important to note, that average adult daily iron intake is 10.5 mg/day (19-64 years)

Source: DH (1991)[7]

Between 2008 and 2019, NDNS data shows a slight decrease in iron intake across age groups, with the largest decline in girls aged 4–10 (-1.4 mg/d), boys aged 11–18 (-1.1 mg/d), men aged 65–74 (-1.1 mg/d) and women over 75 (-1.5 mg/d).[79] According to the 2021 SHeS data,[69] over 40% of the Scottish population, except for men aged 35+, had iron intakes below the RNI.[72] Notably, 97% of teenage girls and young women (aged 16–24) fall short, a trend that persists in women aged 25–34 (93%) and remains high at 75% in those aged 45–54 (Table 24).

Table 24. Percentage of Scottish adults with iron intakes below UK reference nutrient intakes (RNI)

	Age	16–24	25–34	35–44	45–54	55–64	65–74	75+
Iron (mg/d) % below the RNI	Women	97%	93%	93%	75%	57%	58%	48%
	Men	57%	47%	32%	37%	38%	33%	35%

Key: RNI – reference nutrient intake is the amount of a nutrient that is enough to ensure that the needs of nearly all the group (97.5%) are being met; mg/d – milligrams per day. Source: SHeS 2021 data (FSS 2024)[72]

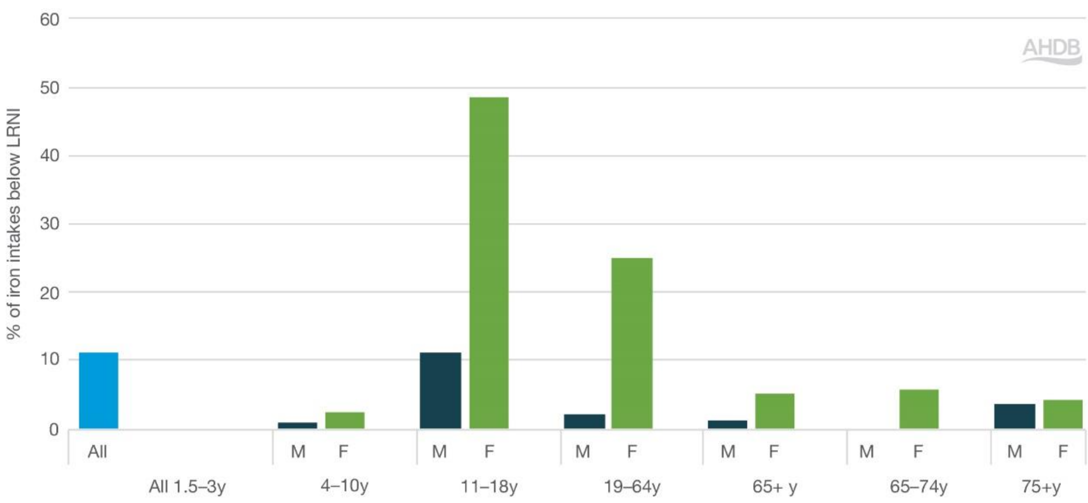
Scottish adolescents have average iron intakes below the RNI: 10.7 mg/day for males (the RNI is 11.3 mg) and 8.0 mg/day for females (the RNI is 14.8 mg). Females aged 15–50 fail to meet the RNI. The LRNI, which meets only 2.5% of the population's needs, is 4.7 mg/day for men and 8.0 mg/day for women aged 19–50, levelling off at 4.7 mg/day for all genders aged 51–75.[7] For adolescents (11–18), the LRNI for girls is 8.0 mg/day – higher than the 6.1 mg/day for boys.

The NDNS reveals that nearly 50% of adolescent girls (11–18) and 25% of women (19–64) do not meet the LRNI for iron (Table 19).[42]

49% of teenage girls have low iron intakes, while 9% have iron deficiency anaemia.

Concerns also extend to very young children (aged 1.5–3 years) and males aged 11–18, with 11% in each group also failing to meet the LRNI. Figure 10 illustrates these trends, emphasising the issue of low iron intake, especially among women, and increased risk of iron deficiency.

Figure 10. Percentage of males and females with iron intakes below the LRNI



Note: The lower reference nutrient intake (LRNI) is the amount considered sufficient for only 2.5% of the population with the lowest physiological requirements, where most people will need more. Intakes below this level could lead to an increased risk of deficiency. Source: NDNS years 9–11 (2016/17 to 2018/19)[42]

The three main stages of iron deficiency are as follows:

1. Iron depletion: this occurs when the body's stores decrease, measurable by ferritin levels in the blood.
2. Iron-deficient erythropoiesis: at this stage, insufficient iron reaches the bone marrow, impairing red blood cell production and causing mild tissue iron deficiency.
3. Iron deficiency anaemia: the most severe stage, where the body cannot produce enough functional iron-containing compounds (such as haemoglobin and ferritin) essential for healthy red blood cells.[80]

NDNS findings on blood markers for haemoglobin (the iron-containing, oxygen-carrying molecule in red blood cells) and plasma ferritin (a protein that stores iron) are shown in Table 20. Low haemoglobin (haem) levels indicate a higher risk of iron deficiency, while low plasma ferritin reflects depleted iron stores. However, elevated ferritin can signal infection or inflammation, so high concentrations should be interpreted cautiously. There may be an underlying infection or inflammatory condition, liver disease or other chronic disorder.[78] The largest population group with low haemoglobin in the UK is men aged 65+ at 15%, compared with 11% of women in the same age group (Table 20), with 13% affected overall. Among adolescents, 17% of girls (11–18) and 15% of women have low plasma ferritin,[42] while only 6% of boys and 1% of men do. In older adults (65+), the 2% with low ferritin may be due to factors other than iron deficiency, such as chronic inflammation, which can elevate ferritin levels and mask true iron levels.[79]

The largest group affected by iron deficiency anaemia is adolescent girls (11–18), with 9% having haemoglobin and plasma ferritin levels below WHO thresholds (Table 20). This rate is 5% for women aged 19–64 and 2% for those over 65. Anaemia in women is exacerbated by menstrual blood loss, impacting 7–62% of women globally.[81] NDNS data indicates 5% of children (11–18) and 3% of adults (19–64) are iron deficient, dropping to 2% for those aged 65+ (Table 20).[42] Additionally, NHS hospital admissions for iron deficiency anaemia in England have more than doubled from 2013–14 to 2022–23, rising from 196,685 to 490,005 cases, indicating a significant year-on-year increase.[67] Table 25 summarises diagnosed deficiencies for key nutrients found in red meat.

Table 25. NHS hospital admissions in England for specific nutrient deficiencies between 2013–14 and 2022–23 for selected nutrients (applicable to red meat).

	Diagnosis description	Year									
		2013–14	2014–15	2015–16	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023–24
Protein related	Unspecified severe protein-energy malnutrition	374	358	429	490	450	512	506	527	518	548
	Protein-energy malnutrition of moderate and mild degree	108	83	134	186	160	146	126	147	128	224
	Retarded development following protein-energy malnutrition	13	1	38	5	6	3	6	5	6	6
	Unspecified protein-energy malnutrition	5,746	6,359	6,625	7,151	8,022	8,833	8,671	8,856	9,450	9,390
B-vitamin related	Thiamine deficiency	784	860	1,088	1,163	1,274	1,538	1,551	1,991	2,042	1,963
	Niacin deficiency (pellagra)	7	3	6	6	11	9	22	25	15	22
	Vitamin B12 deficiency anaemia	20,454	20,722	21,389	22,397	23,305	24,323	25,145	19,811	24,497	24,694
	Deficiency of other B group vitamins	27,689	32,195	37,872	51,306	64,429	78,636	90,477	84,034	109,109	120,475
Vitamin D related	Vitamin D deficiency	31,576	40,460	55,372	76,144	101,606	125,951	142,549	136,379	179,607	188,144
	Rickets, active	498	530	529	445	474	477	504	391	439	482
Iron deficiency anaemia		196,685	217,718	252,759	285,506	317,821	364,843	396,793	333,059	116,836	490,005
Dietary zinc deficiency		134	107	118	155	156	143	218	224	248	219
Dietary selenium deficiency		46	20	28	34	40	50	73	67	128	92
Deficiency of other nutrient elements		6,174	6,578	8,289	10,256	13,243	17,188	21,403	18,110	26,034	29,277

Source: NHS (2023)[67] **https://digital.nhs.uk/supplementary-information/2023/hospital-admissions-with-a-diagnosis-of-rickets-and-vitamin-deficiency**

Implications of iron deficiency

Higher rates of iron deficiency in women, girls and young children suggest significant health implications, including impacts on internal function, cognitive development and overall health and wellbeing. Symptoms may include lower energy levels, reduced productivity, impaired cognitive and immune function and complications related to pregnancy outcomes. Table 26 outlines the symptoms of iron deficiency anaemia in adults.

Table 26. Symptoms of iron deficiency anaemia in adults

Symptoms
Tiredness and a lack of energy
Paler than usual skin
Pica (a desire to eat non-food items)
Heart palpitations
Poor concentration
Headaches
Ringing or buzzing in the head (tinnitus)
Differences in food taste
A sore tongue
Difficulty swallowing
Feeling itchy
Spoon-shaped nails

Sources: NHS (2024b)[82]; Zimmerman and Hurrell (2007)[83]

As plant-based diets rise and meat consumption decreases to combat climate change, monitoring changes in iron intake and status since 2019 is crucial. Vulnerable groups, such as babies, infants, young children, adolescents and women of childbearing age, have increased iron needs due to growth, menstruation and pregnancy, making them more susceptible to iron deficiency.

NDNS data shows a consistent reduction in red and processed meat consumption across all age groups since 2008, with declines of 13–23 g/day.[42] The FSS report (2024) also reveals significant proportions of the Scottish population are below the RNI for iron, particularly 97% of younger women and 53% of men aged 16–24 (Table 24). Over 90% of Scottish women of childbearing age (16–44) also do not meet the iron RNI. The key point is that this is occurring before the CCC targets to reduce meat intake by 20% and 30% have been implemented.[72] The impact of dietary changes on the iron status of these vulnerable groups warrants further analysis, particularly in the context of climate targets and dietary-based guidelines.

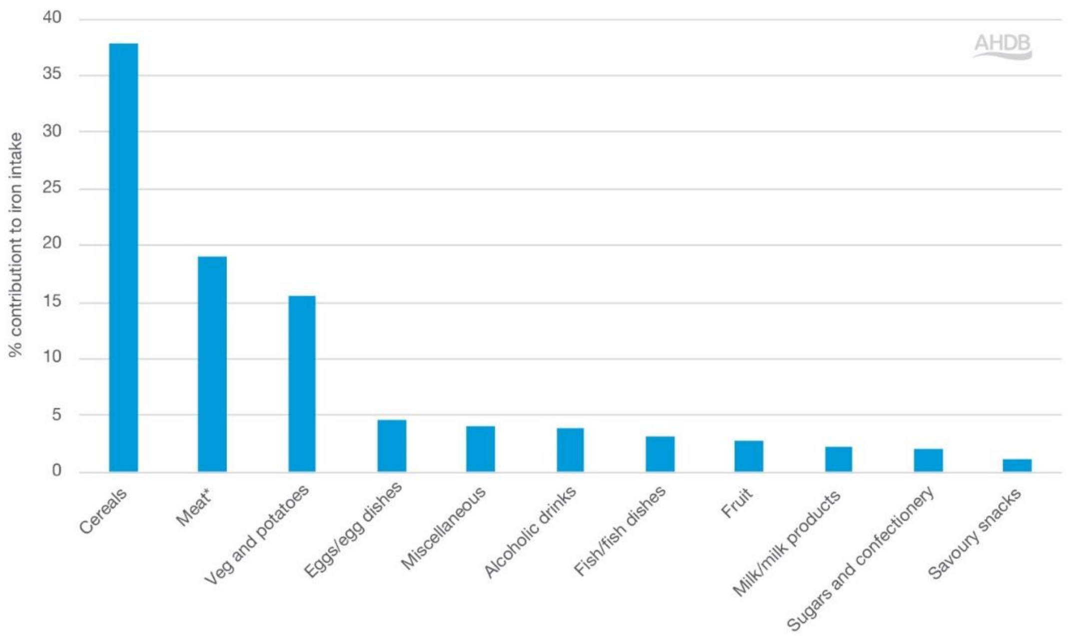
Contributions of food categories, including red meat to iron intakes

NDNS data provides evidence that the key sources of dietary iron intake for adults aged 19–64 are cereals and cereal products (38%), followed by meat and meat products (19%) and red meat (7%) (Figure 11). Among red meats, beef is the largest contributor, providing 5% of iron intake, compared with lamb and pork, which provide 1% each.[42] A recent study found that grass-fed Welsh lamb has higher iron content than lamb from indoor concentrate-based diets,[38] suggesting that grass feeding lambs increases iron levels in red meat.

> **"Meat and meat products' provide 19% of iron in adults aged 19–64 (7% from red meat)"**

Vegetables and potatoes account for the second-largest contribution to iron intake (16%), following cereals and cereal products (38%). Together, these two categories contribute over 54% of total iron intake.[42] Other animal-based products – milk, eggs, and fish – provide approximately 10% of adult intakes, demonstrating lower overall contributions of meat and animal products (just under 30%). A key concern is the body's ability to absorb iron from different sources; around 70% of dietary iron comes from plant-based sources, which contain less readily absorbable iron compared with meat.

Figure 11. Percentage contribution of different food groups to UK dietary iron Intake in adults aged 19–64 years



*Of the contribution from meat, red meat provides 7% of iron (5%, 1% and 1% for beef, lamb and pork, respectively)

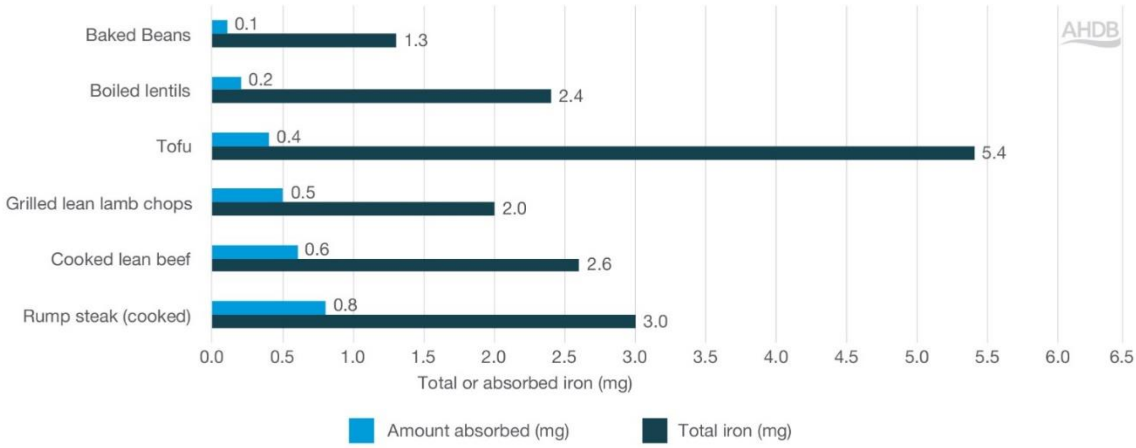
Source: NDNS data[42]

Iron bioavailability in animal versus plant-based food sources

Animal-based foods such as meat, fish and poultry provide haem iron, the most bioavailable form of iron.[78] Haem iron makes up 40–85% of the iron in meat, with red meat offering the highest haem iron levels, while white meat, such as chicken, contains less.[84] This readily absorbable haem iron significantly enhances overall iron absorption. In contrast, plant-based foods, including beans, pulses, nuts, green vegetables and grains, contain non-haem iron, which is absorbed less efficiently.[78] Consequently, vegetarians and vegans may need to consume nearly twice the amount of iron compared with meat eaters.[85]

While only 10–15% of iron intake in an omnivorous diet comes from haem iron, it accounts for over 40% of total iron absorbed due to its higher bioavailability.[86] Thus, although red meat contributes about 7% of iron intake in the UK,[42] its actual impact on iron absorption is much greater. For example, 120 g of fried lean rump steak provides 3.8 mg of total iron, with 0.9 mg absorbed. In comparison, 100 g of tofu contains 5.4 mg of total iron, but only 0.4 mg is absorbed, less than half what the steak provides. This illustrates how even small amounts of red meat can significantly contribute to iron intake compared with plant-based sources. Other examples are shown in Figure 12.

Figure 12. Total iron content in selected red meats compared to plant-based foods



Source: New Zealand Institute for Plant and Food Research Limited and Ministry of Health (2021)[87] cited in Iron Absorption (2020) Beef & Lamb New Zealand

The European Food Safety Authority (EFSA) reports that haem iron absorption from a Western diet is approximately 25%.[88] In contrast, plant-based sources contribute roughly 70% of iron intake in the UK[42] but have a lower absorption rate of around 8%.[86, 89, 90] This highlights the significant difference in iron absorption between animal and plant-based foods.

To enhance absorption of non-haem iron from plants, especially in the presence of inhibitors, it is essential to consume vitamin C alongside these sources to aid the absorption. Vitamin C can increase non-haem iron absorption two- to threefold;[91] about 100 mg of vitamin C can boost non-haem iron absorption by up to 67%.[92]

Plant-based foods often contain anti-nutrients, such as phytates in whole grains and beans, which can reduce mineral absorption, including iron and zinc. Other anti-nutrients include trypsin inhibitors and tannins, such as those found in tea.[93, 94] These compounds serve as a protective mechanism for seeds, ensuring their survival until planted.[95]

Mineral absorption from plant-based foods can be improved through specific processing methods. Soaking and rinsing dried beans or fermenting grains can decrease phytate levels, enhancing iron uptake.[86,96] However, these methods require time and planning, and many consumers may lack awareness of these techniques, highlighting the need for educational efforts. The role of conventional processing methods in incorporating these measures is also unclear.

The body can adjust iron absorption, based on need. For instance, individuals with iron deficiency absorb more dietary iron. Research has shown that absorption rates increase from 0.9% in individuals with normal iron levels to 2.5% in those with moderate and 5.7% in those with severe iron deficiency.[97] When iron stores are low or depleted, non-haem (plant-based) iron absorption can increase tenfold, while with haem (animal-source) iron, absorption only doubles,[98] suggesting a greater adaptive response for non-haem iron benefiting vegetarians or vegans when deficient or at risk of deficiency.

However, the mechanisms of iron absorption are still not fully understood,[80] particularly for haem iron, due to limited research and methodological issues.[79] Comparisons of iron absorption rates in vegetarians, vegans and omnivores often face confounding factors, and the lack of randomised controlled trials complicates establishing causality. More extensive and long-term research is needed to observe meaningful changes in iron status over time and to better understand the absorption processes. Additionally, findings from different studies often cannot be directly compared.[79] While there is speculation about the body's adaptive mechanisms for iron uptake, more research is required to understand the nuances of this process, especially in relation to different dietary patterns, such as vegetarian or vegan diets.[79]

Incorporating meat into meals with plant-based iron sources enhances the absorption of non-haem iron due to the haem iron in meat, known as the meat factor. This increases the bioavailability of minerals including iron from plant-based foods.[85] A UK health claim supports this, stating that consuming 50 g of meat or fish with non-haem iron-rich foods improves iron absorption (Table 20).[5]

Adding meat into meals that contain plant-based iron aids the absorption of non-haem iron, increasing the bioavailability of the iron present, known as the meat factor.

The type of meat and different cooking methods affect the bioavailability of haem iron.[99] Data on raw meat is less relevant. A database has been developed that considers meat type, cooking method and the extent to which meat is cooked.[100] Notably, steak boasts the highest haem iron levels at 9.3 µg/g, while pork ranges from 3.4 to 7.5 µg/g, and chicken breast has lower levels at 2.4 µg/g.[79]

Recent studies reveal a significant difference in iron bioavailability between ruminant meat and plant-based sources such as pulses.[73] While adequate iron intake is essential for preventing iron deficiency anaemia, it is crucial to consider the interplay between iron and other micronutrients such as vitamin A and B vitamins for optimal health.[101] Even if vegetarians or vegans meet recommended iron intake levels, deficiencies in these supporting nutrients can still result in low iron stores and related health problems. Understanding iron bioavailability and its interaction with other nutrients highlights the importance of considering the overall diet composition for better health. Incorporating this knowledge into discussions about dietary choices can help individuals make more informed nutritional choices and promote nutritional health and wellbeing.

This information highlights the need for careful dietary choices that can support optimal iron and micronutrient absorption, particularly for those reducing or eliminating meat in vegetarian or vegan diets. Understanding diverse absorption rates is crucial for ensuring nutritional adequacy. It is also imperative to promote education on food choices, meal planning and recipes that enhance iron absorption. For example, a beef-based cottage pie with beans, pulses and root vegetables demonstrates a nutritionally conscious meal approach. This holistic understanding empowers individuals to make informed dietary choices, contributing positively to their overall health and wellbeing.

Zinc

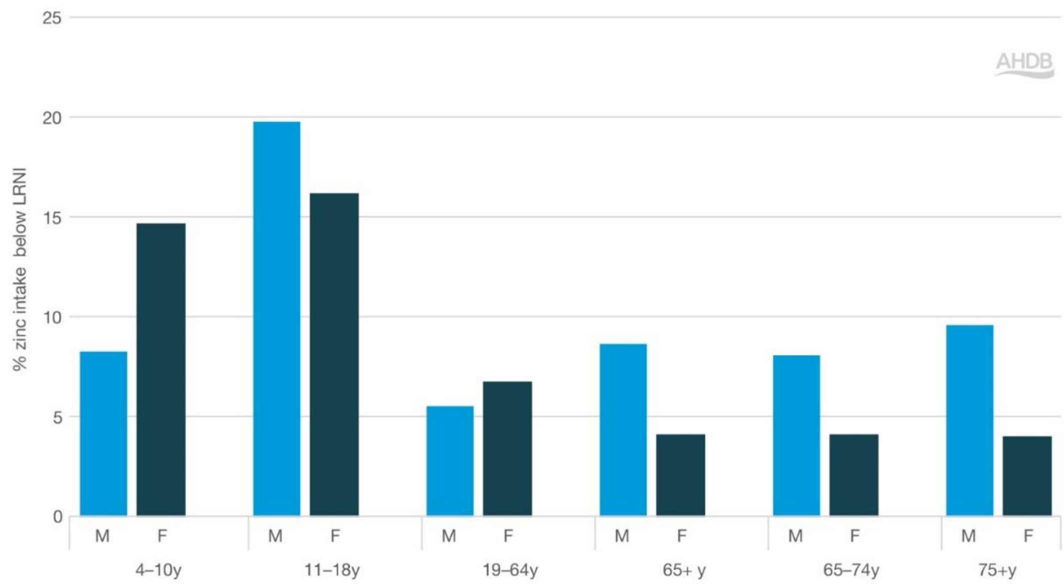
Zinc provides numerous health benefits, including macronutrient metabolism (carbohydrates and fatty acids protein synthesis), maintenance of bones, hair, skin and nails and playing a crucial role in fertility, testosterone and DNA synthesis and cell division. Dietary zinc also helps protect against oxidative stress and supports cognitive and vision functions (Table 18).[5]

Zinc intakes, status and risk of deficiency

The RNI for zinc is 7 mg/day for women and 9.5 mg/day for men aged 15–50, while the LRNI is 5.5 mg/day and 4 mg/day, respectively. For teenagers (11–14), the RNI is 9 mg/day and the LRNI is 5.3 mg/day to support their growth and development needs during puberty, with younger children needing less. Breastfeeding women require an additional 2.5–6 mg of zinc per day in addition to the adult RNI.[7] The NDNS reports average zinc intake at 8.6 mg/day for adults (19–64) and 7.2 mg/day for adolescents.[42]

Among adolescents (aged 11–18), 20% of boys and 16% of girls are at risk of zinc deficiency, with 15% of girls and 8% of boys (aged 4–10) also at risk. Eight percent of very young children (aged 1.5–3) are similarly affected. While the risk of deficiency decreases into adulthood, it rises to 10% for men aged 75+ (10%) (see Figure 13). However, since the LRNI meets the needs of 2.5% of the population, not everyone in these age groups is necessarily at risk of deficiency.

Figure 13. Percentage of males and females with zinc intakes below the LRNI



Key: LRNI – lower reference nutrient intake is the amount considered sufficient for only 2.5% of the population with the lowest physiological requirements, where most people will need more. Intakes below this level could lead to an increased risk of deficiency.

Source: NDNS[42]

The higher LRNI figures for boys and girls are concerning, given zinc's vital role in fertility, reproduction, DNA synthesis and cognitive function during critical learning stages.[5] Data from the 2021 Scottish Health Survey (SHeS)[69] shows over 40% of Scottish adults have zinc intakes below the RNI.[72] Average intakes range from 7–8.5 mg/day, with all men aged 15–51 falling short of the RNI (9.5 mg/day), while women in the same age group meet the RNI (7 mg/day). Between 58–78% of men and 51–63% of women have intakes below the RNI, with women's intake improving with age (63% for ages 16–24, versus 48% for ages 75+). In contrast, zinc intakes worsen for men, with 78% of those aged 75+ not meeting recommended levels (Table 27). Such high figures raise concerns about the population's ability to meet zinc-related health needs.

Table 27. Percentage of Scottish adults below UK reference nutrient intakes (RNI) for zinc

	Age	**16–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65–74**	**75+**
Zinc (mg/d) % below the RNI	Women	63%	61%	51%	51%	56%	56%	48%
	Men	69%	69%	58%	66%	75%	71%	78%

Key: RNI – reference nutrient intake is the amount of a nutrient that is enough to ensure that the needs of nearly all the group (97.5%) are being met.

Source: SHeS 2021 data (FSS 2024)[72]

Interestingly, NHS hospital admissions in England for zinc deficiency have almost doubled over the past decade, with diagnosed cases rising from 134 to 219 between 2013/14 and 2022/23 (Table 25).[67] This data indicates significant concerns regarding zinc intake and status in the UK diet.

Implications of zinc deficiency

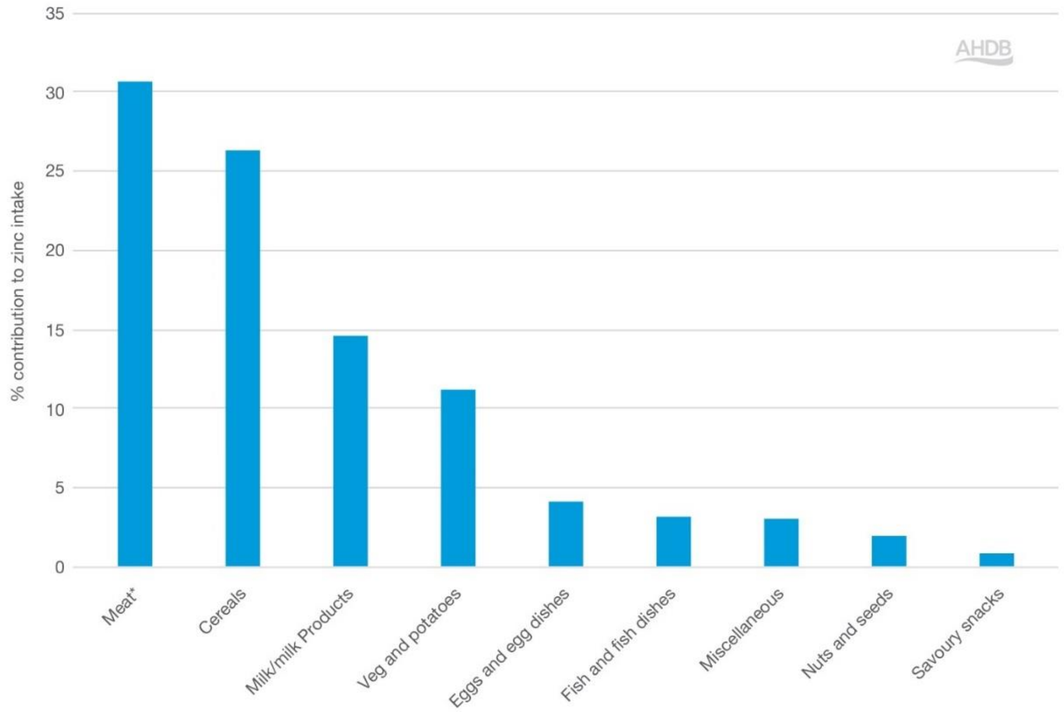
A detailed review of zinc deficiency, including its current status and potential solutions, is provided by Knez and Stangoulis.[102] It is estimated that 17–20% of the global population is affected by zinc deficiency,[103] which is a major health risk factor, ranked fifth in the developing countries and eleventh worldwide.[104,105] Zinc deficiency poses significant health risks, especially in children from lower-income countries, leading to growth inhibition, weakened immune function and higher susceptibility to infections such as diarrhoea and pneumonia[106–108] and potentially sepsis[107,108] and asthma.[109] Zinc deficiency is linked to growth stunting and increased morbidity and mortality.[110] Even marginal zinc deficiency can cause hypogonadism, delayed puberty, mental fatigue, dermatitis and immune dysfunction.[111]

Food category contributions, including red meat to zinc intakes

According to NDNS data, the largest source of zinc for adults aged 19–64 is meat and meat products, contributing 31% of total zinc intake. Of this, red meat accounts for 14%, with beef providing 10% and lamb and pork each contributing 2%. The remaining 17% includes other meat types, including processed meat (Figure 14).[42]

The second-largest source of zinc is cereals and cereal products, supplying 26% of zinc, particularly for children aged 4–18, where it rises to 30%. Milk and milk products also provide 15% of zinc in adults aged 19–64, while vegetables and potatoes contribute 11% .[42]

Figure 14. Percentage contribution of different food groups to dietary zinc intake in UK adults aged 19–64



Key: *Of the contribution from meat, red meat provides 14% of zinc (10%, 2% and 2% for beef, lamb and pork, respectively)

Source: NDNS data [42]

Zinc bioavailability in animal versus plant-based food sources

Zinc bioavailability depends on several factors, including total dietary intake, individual zinc status and its solubility in the intestine.[112] Meeting the recommended dietary zinc intake does not guarantee adequate zinc status as absorption is influenced by the source (animal or plant origin) and the presence of inhibitors such as phytate.[113] For those with low zinc status, absorption is affected by the type of zinc consumed and the presence of absorption enhancers or inhibitors.[114] Adults consuming diets with higher zinc bioavailability can regulate absorption to meet their needs, typically around 4–5 mg per day, with adjustments observed within four weeks but not significantly at eight weeks.[115,116] Overall, prolonged low zinc status, whether through interacting dietary factors, and the presence of phytates enhance absorption,[102] but more research is needed to fully understand how different dietary patterns affect zinc nutrition over time.

Phytates found in cereal grains, nuts, seeds and legumes can bind to zinc in the intestine, significantly reducing its absorption.[113,118] Diets high in phytates are linked to zinc deficiency.[117] Red meat offers 4.5–5.2 mg of zinc per 100 g, while nuts and seeds typically consumed in smaller amounts (25–30 g) than larger meat portions (130 g steak) provide 6.5–7.8 mg per 100 g (RNI for men is 9.5 mg/day and for women is 7 mg/day).[119] Grains provide

0.3–2.54 mg of zinc per 100 g[119] and half that of red meat. Zinc bioavailability is 1.7 times higher in ruminant meat than in pulses, such as beans, peas and lentils.[73] While cereals and cereal products are the second-largest contributor to zinc intake[42] (page 84), their high phytate content hinders zinc absorption. Humans lack the phytase enzymes to break down phytic acid to release the bound zinc for absorption.[116,120] However, as previously highlighted, phytates can be reduced through preparation methods such as soaking, germination, fermentation and milling,[121] though it is unclear whether consumers or food manufacturers consider this, given the time required for these mitigation steps.

In its report on Iron and Health, SACN (2010) found that reducing red meat consumption from 90 to 70 g/day increased the proportion of men with zinc intakes below the LRNI by 5%. Given zinc's vital role in fertility and cognitive function, intakes below 70 g/day significantly increase deficiency risks. Additionally, for every 10 g decrease in meat consumption (down to 50 g), average iron intake in women decreased, leading to more individuals falling below the LRNI for both iron and zinc.[78] A more recent Food Standards Scotland report, which was reviewed by SACN,[72] has demonstrated that further reductions in meat intake beyond the current health recommendations of <70 g per day to meet climate targets[122] could have serious consequences for zinc and iron intake and status, particularly in already nutritionally vulnerable population groups.[72]

In conclusion, the factors affecting zinc absorption, along with superior bioavailability of zinc in red meat compared with plant sources, highlight the importance of including meat as part of a healthy, balanced diet. Individuals primarily consuming plant-based foods should aim for a higher zinc intake to compensate for lower absorption rates.[123] Similarly, those reducing consumption of animal-based foods should consider including smaller portions of red meat to maintain adequate zinc levels. This balanced approach ensures sufficient zinc nutrition while accommodating diverse dietary preferences.

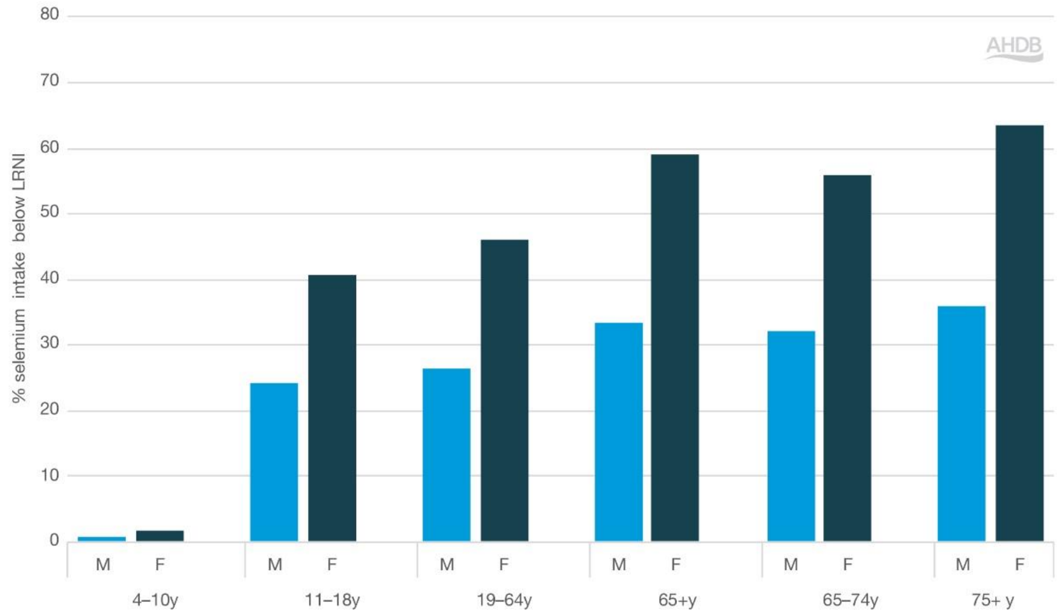
Selenium

Selenium uniquely supports sperm production and, alongside iodine, helps maintain normal thyroid function. It protects cells from oxidative stress, supports healthy hair and nails and contributes to immune function (Table 18).[5]

Selenium Intakes, status and risk of deficiency

The RNI for selenium is 60 µg/day for those aged 15–75+, with an LRNI of 40 µg/day. Adolescents, children and infants require less, while breastfeeding women need an additional 15 µg/day.[7] The most recent NDNS data shows average adult selenium intake at 51 µg/day, below the RNI. Of all LRNI micronutrients reported, selenium was high across all age groups, indicating a high risk of selenium deficiency (Table 19; Figure 15). Among women, 63% of those aged 75+ have intakes below the LRNI, followed by 59% of women aged 65+ and 46% of those aged 19–64. Males also show low intake levels, with 24%, 26% and 34% of boys aged 11–18, men aged 19–64 and men aged 65+, respectively.[42]

Figure 15. Percentage of males and females with selenium intakes below the LRNI



Key: LRNI – lower reference nutrient intake is the amount considered sufficient for only 2.5% of the population with the lowest physiological requirements, where most people will need more. Intakes below this level could lead to an increased risk of deficiency.

Source: NDNS[42]

Scottish dietary data reveals that over 40% of adults have selenium intakes below recommendations, with 87–95% of women and 87–91% of men not meeting the RNI (Table 28).[72] Women consistently show mean intakes below the LRNI – with averages of 32 µg/day for ages 15–18, 37 µg/day for 19–50 and 38 µg/day for those aged 51+ years, respectively, compared with the LRNI of 40 µg/day. This aligns with NDNS data, showing reduced selenium intake in females. However, SACN notes that while reported selenium intakes are low, there is currently insufficient evidence to deem this a public health concern.[124]

Table 28. Percentage of Scottish adults not meeting UK reference nutrient intakes (RNI) for selenium

	Age	16–24	25–34	35–44	45–54	55–64	65–74	75+
Selenium (µg/day) % below the RNI	Women	95%	92%	87%	88%	88%	92%	91%
	Men	90%	87%	86%	91%	91%	91%	91%

Key: RNI – reference nutrient intake is the amount of a nutrient that is enough to ensure that the needs of nearly all the group (97.5%) are being met.

Source: SHeS 2021 data (FSS 2024)[72]

NHS hospital admissions data indicates that cases of selenium deficiency in England has more than doubled over the last decade, with 20–128 cases of selenium deficiency cases recorded to date.[67]

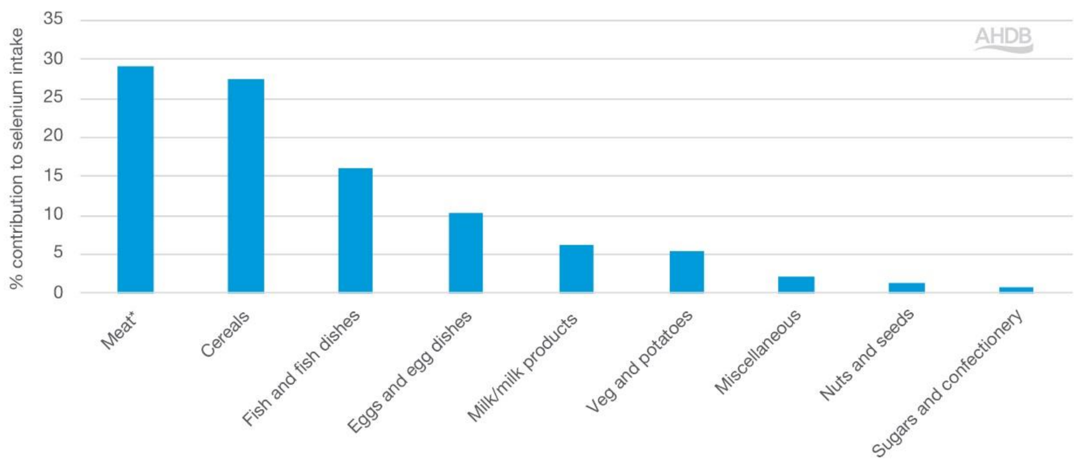
Implications of selenium deficiency

Selenium deficiency affects 500 million to one billion people worldwide, primarily due to inadequate intake.[125] It can lead to several different systemic health problems, including the cardiovascular, endocrine, immune, musculoskeletal, reproductive, neurological and psychiatric systems.[126]

Food category contributions, including red meat to selenium intake

Meat and meat products (29%) make the biggest contribution to selenium intake for 19–64-year-olds, followed by cereals and cereal products (27%), fish and fish dishes (16%) and eggs and eggs dishes (10%) (Figure 16).[42]

Figure 16. Percentage contribution of different food groups to UK dietary selenium intake in adults aged 19–64



Key: *Of the contribution from meat, red meat provides 7% of selenium (4%, <1% and 2% for beef, lamb and pork, respectively)

Source: NDNS data[42]

Role of red meat in meeting nutritional needs at different life stages

Building on previous sections, red meat serves as an important source of high-quality protein and a variety of essential nutrients. These nutrients are fundamental to maintaining and regulating essential bodily functions (summarised in Tables 17 and 18). Red meat can provide key nutrients often lacking in some populations, such as vitamin B12, and provides highly bioavailable forms of iron and zinc, also contributing to omega-3 intake.[42,73] Our nutritional needs change throughout life, influenced by age, gender and life stages, like growth, reproduction and ageing. Red meat and other animal-sourced foods are nutrient dense and help promote a healthy, balanced diet throughout the life course, as emphasised in the recent FAO report.[127] This report, based on over 500 scientific studies and 240 policy documents, highlights the global importance of these foods in meeting dietary requirements across the lifespan.

Summarising insights from the FAO report, Table 29 focuses specifically on the nutrients supplied by red meat and their respective health functions at various stages of life. Red meat contributes high-quality protein for muscle growth and repair, essential fatty acids for cognition, neurodevelopment and anti-inflammatory processes, iron to prevent iron deficiency anaemia, zinc for growth and immunity and vitamin B12 for neurodevelopment.[127] While the FAO provides a global perspective, specific considerations for Great Britain (GB) are also included in Table 29.[5] Overall, the table demonstrates how red meat can make a useful contribution in each life phase, where certain times are more critical than others, that is, during pregnancy and lactation, infancy and early childhood, in women of reproductive age, adolescents and older adults.

Table 29: Nutrients needed for health functions during specific life stages as provided by red meat

Life-course stage	Nutrients	Important health functions	Ref. source
Infants and young children (6–59 months, including 6–23 months)	Protein	Healthy growth	FAO
	Fatty acids (DHA)	Necessary ratio of essential fatty acids	
	Iron	Cognitive development	
	Vitamin B12 and iron	Immune system function	
	Zinc	Vision health	
	Riboflavin	Maintenance of red blood cells	DHSC
School age children (5–9 years)	Protein	Healthy growth	FAO
	Fatty acids (DHA)	Necessary ratio of essential fatty acids	
	Vitamin B12 and zinc	Immune system function	
	Iron and zinc	Normal cognitive function and brain development	
	Riboflavin	Maintenance of red blood cells	DHSC
	B-vitamins	Reducing tiredness and fatigue	
Adolescents (10–18 years)	Protein	Healthy growth	FAO
	Fatty acids (DHA)	Necessary ratio of essential fatty acids	
	Vitamin B12	Immune system function	
	Zinc	Fertility and reproductive maturation	
	Iron and zinc	Normal cognitive function and neuroplasticity	

	Selenium	Sperm and testosterone production Thyroid function	DHSC
	Riboflavin	Vision	
	Vitamin B6	Maintenance of red blood cells	
	B-vitamins	Hormonal activity	
		Reducing heart disease risk (homocysteine levels)	
Women of reproductive age, including during pregnancy and breastfeeding (15–49 years)	Protein	Full-term infant	FAO
	Fatty acids (DHA)	Breast milk quality	
		Necessary ratio of essential fatty acids	
	Iron	Anaemia prevention	
		Supporting increasing blood volume	
	Zinc	Lower risk of infection/immunity	
	Riboflavin	Maintenance of red blood cells	DHSC
	B-vitamins	Reducing tiredness and fatigue	
Adults (18–65 years)	Protein	Muscle mass maintenance	FAO
	Fatty acids (DHA)	Necessary ratio of essential fatty acids	
		Cognitive maintenance and healthy nutrient levels	
	Vitamin B12	Immune system function	
	Zinc	Memory and cognitive preservation	

		Fertility and reproduction	
	Selenium	Sperm and testosterone production	DHSC
		Thyroid function	
	Riboflavin	Vision	
	Vitamin B6	Maintenance of red blood cells	
	B-vitamins	Hormonal activity	
		Reducing heart disease risk (homocysteine levels)	
		Reducing tiredness and fatigue	
Older adults (65+ years)	Protein	Muscle mass maintenance	FAO
	Fatty acids (DHA)	Necessary ratio of essential fatty acids	
		Immune system function	
	Vitamin B12	Memory and cognitive preservation	
	Riboflavin	Maintenance of red blood cells	DHSC
	B-vitamins	Reducing tiredness and fatigue	

Key: DHA = Docosahexaenoic acid.

Source: Adapted from FAO (2023b)[127] and DHSC (2023)[5] to reflect the nutrients provided by red meat. Specifically, FAO Table C1: Effects of terrestrial animal source food on health and nutrition over the life course. In the absence of clear signposting within the original FAO table, efforts have been made to align nutrients with functionality.

Please note: The FAO entails functional considerations at a global level, whereas the DHSC entails functional considerations for those residing in Great Britain (GB). This includes the addition of other B-vitamins and selenium, due to their health functions of relevance to different life stages, as defined by the GB Register of Nutrition and Health Claims (DHSC 2023)[5]. The latter can be cross-referenced with Tables 17 (Vitamins) and 18 (Minerals) to understand the precise role of the different micronutrients cited (also see DHSC 2023).[5]

Nutritional needs for pregnant and lactating women

During pregnancy and lactation, women have increased nutrient needs to support both the mother and her baby. This includes providing iron-rich blood to the developing foetus, reducing infection risk and ensuring a healthy supply of breast milk which delivers essential nutrients to the growing baby. Natural nutrient-dense foods, like red meat, can play a significant role in meeting these dietary requirements (Table 30).

Adequate protein intake is also essential for meeting the nutritional demands placed on both the mother and baby, particularly during the last trimester of pregnancy and while breastfeeding. The NHS recommends daily consumption of protein-rich foods, like beans, pulses, fish, eggs, meat and poultry.[128] Pregnant women need an additional 6 g of protein per day, while breastfeeding mothers require an extra 11 g during the first six months, decreasing to +8 g per day thereafter as the baby progresses to solid foods (Table 5).

In the UK and the EU, iron requirements for pregnant women are the same as for non-pregnant women,[7,129] with women of childbearing age requiring 14.8 mg per day.[7] The FAO/WHO guidelines[130] align with this, while the USA and Canada recommend 1.5 times higher iron intake during pregnancy.[131] Higher iron requirements continue during breastfeeding, and inadequate intake can affect the nutritional composition of breast milk, including vitamin B12, choline and essential fats.[132] Red meat consumption has been shown to reduce iron deficiency in breastfed infants with low iron intake and storage levels.[133]

A recent study investigated maternal B-vitamin status, before, during and after pregnancy, where it focused on supplementation requirements.[134] Participants who were planning pregnancies were recruited and their dietary patterns analysed. The findings showed a very concerning trend: many women in high-income countries had insufficient vitamin levels, with some experiencing vitamin B6 deficiency in late pregnancy. Furthermore, without adequate supplementation, vitamin levels declined during pregnancy despite having adequate levels before pregnancy, predisposing women to deficiencies in vitamins B6 and B12.

Given the rise in popularity of plant-based diets in higher-income countries, particularly when whole food groups are removed without adequate replacements, the authors argue for a re-evaluation of dietary recommendations for women before and during pregnancy to ensure optimal nutrient intake. The study underscores the importance of consuming a healthy, balanced diet, rich in nutrient-dense foods, such as red meat, to provide essential micronutrients like vitamin B6 and B12 during pregnancy and lactation. By recognising the importance of nutrient-rich animal-sourced foods including red meat, dairy, oily fish and eggs, healthcare professionals can better support maternal health and optimise pregnancy outcomes. If these foods are excluded, guidance on suitable alternatives is crucial to ensure nutritional adequacy.

To tackle global micronutrient deficiencies, researchers created a comprehensive food composition database to identify primary sources of essential micronutrients.[73] The study evaluated the nutritional profiles of various foods against the micronutrient needs of women of reproductive age, emphasising the role of red meat and other nutrient-dense foods during critical phases of development, particularly the first 1000 days of life. Beef and lamb ranked ‘very high’ in terms of their nutrient density, while pork, although still ‘high’, exhibited slightly lower nutrient density, with lower values per calorie and per gram of food.

Infants and young children

During weaning, infants and young children derive essential amino acids, iron, zinc and vitamin B12 from animal-sourced foods.[135] Their rapid growth and development necessitates a high-quality diet, rich in protein to support growth and development of bones.[5] Due to very young children having small stomachs, nutrient-dense foods are required to meet all their energy and nutrient needs. Protein malnutrition is less common in developed countries, which can hinder physical and mental development. Consequently, infants and young children require high-quality protein sources with every meal.

During this rapid growth and development phase, adequate micronutrients are essential for children’s health, brain function and cognitive development. Research indicates that 1.6 billion preschool children and women of reproductive age worldwide are deficient in key micronutrients, with 56% of preschool children deficient in one or more of: iron, zinc and vitamin A.[136] These micronutrients are vital for growth, vision cognitive function and immune support (Table 29). Red meat, while not a source of vitamin A, provides important levels of iron and zinc, which contribute to overall health and wellbeing during this crucial period (see Tables 17 and 18).

Systematic reviews, meta-analyses and randomised control trials (RCTs) also demonstrate that meat and dairy products positively influence child growth.[137] Red meat consumption significantly increases children's body length for their age.[138] Furthermore, a systematic review on introducing solid foods to babies in higher-income countries found that including meat primarily red meat can reduce the risk of iron deficiency in breastfed infants, especially when their iron intake is low or their iron stores are insufficient during the first year of life.[133]

Schoolchildren and adolescents

Older children and adolescents experience rapid growth, especially during puberty, which increases their requirements for protein, essential fats and various micronutrients. This developmental period also emphasises learning, cognitive function and brain development requiring amino acids, essential fats and micronutrients like iron and zinc (Table 29).[5] Additionally, as children interact with each other in school and preschool settings, their immune systems face greater exposure to viruses and pathogens, impacting immune system function.

As older children transition to adulthood, puberty imposes additional demands on their developing bodies. A period characterised by rapid growth, reproductive organ maturation and brain rewiring occurs with new learning experiences, in preparation for adult life (Table 29). Essential nutrients from red meat like high-quality protein, essential fats, B-vitamins, iron, zinc and selenium help support this nutritionally demanding stage of life.

A systematic review examining the effects of beef consumption on cognitive outcomes in children and young adults showed positive effects on cognitive outcomes.[139] Research with Kenyan school children provides clear evidence that those children consuming meat in school feeding trials scored higher on cognitive ability tests than those receiving other protein sources like milk or githeri (traditional Kenyan maize and bean casserole).[141,142,143] Additional findings from the research indicated that meat consumption is linked to lower morbidity[140], increased physical activity, improved group leadership skills and greater muscle growth compared to other protein sources. Overall, these research findings suggest that meat consumption has positive effects on cognitive outcomes, muscle growth and overall nutrition during childhood and adolescence.

Adults, especially women of reproductive age and older adults

During adult life, adequate protein intake is vital for maintaining muscle mass, while cognitive function and memory is dependent on essential nutrients, like fats, iron and zinc. The B-vitamins, including thiamine, niacin, vitamin B6 and vitamin B12, are important for psychological function and health.[5]

To assess the impact of red meat consumption on cognitive function in adults, the UK Biobank that includes data from over 500,000 adults aged 40–69 was examined. Analysis of food frequency questionnaires alongside cognitive function tests revealed that higher consumption of unprocessed meat correlates with higher cognitive ability.[144] Similar positive associations were observed for habitual fish consumption and moderate fibre intake. Surprisingly, higher vegetable intake was linked to lower cognitive ability, and no association was found between processed meat intake and cognitive ability.

Red meat is a good source of protein and B-vitamins, while fish consumption provides essential macro and micronutrients; the authors suggest that the positive associations observed with cognitive ability may be linked to a) B-vitamins, b) omega-3 fatty acids, c) proteins or d) protein-rich dietary patterns (e.g. the DASH diet). Further research is needed on how the different diet patterns and food groups affect cognitive function.

During reproductive years, women need twice as much iron as men due to menstrual blood loss.[131] Women require 14.8mg/day compared to 8.7 mg/day in men in the UK. However, it is extremely concerning that many women of reproductive age in the UK do not get enough iron and zinc, which are crucial for reproductive health, growth and development.[42,145] In the USA, iron deficiency among women of reproductive age has risen from 13% to 20% between 2004 and 2016[146], partly due to a 15% decline in red meat consumption.[147] A similar trend is observed in the UK, where 20% of women of reproductive age are iron deficient, and coincides with reduced red meat consumption.[42]

For older adults, maintaining muscle mass becomes paramount in combating age-related muscle wasting, or sarcopenia. Malnutrition poses a significant threat to this demographic, affecting one in ten older adults in the UK – over one million people.[148] This condition leads to poorer health, increased hospital admissions and long-term health problems.[149] Malnutrition is prevalent in residential care homes (55%), hospitals (44% of patients) and among older adults living independently (56%).[150] There is also a misconception that weight loss and frailty are a normal part of ageing, but inadequate protein intake plays a key role in sarcopenia.[151] Older adults often consume less food, including protein, and coupled with reduced activity levels and changing appetites, this increases their risk of frailty and micronutrient deficiencies.

Incorporating nutrient-dense foods, like red meat, into the diet is essential for older adults, regardless of their residential setting. Red meat serves as an excellent source of high-quality protein and essential vitamins and minerals, making it especially valuable for those with increased nutritional needs.[5] A systematic review highlighted the benefits of consuming lean red meat for muscle health and protection against sarcopenia.[152] Beal and Ortenzi (2022)[73] suggested that older adults would benefit from the inclusion of protein from both plant and animal sources. Including red meat as part of a healthy, balanced diet can support muscle mass, cognitive function, memory and immune health, promoting healthy ageing and, ultimately, quality of life (Table 29). Regular physical activity is also crucial for maintaining muscle mass alongside protein intake.

By including red meat as part of a healthy, balanced diet, individuals can support their muscle mass, cognitive function and memory preservation needs, as well as help maintain immune system function, promoting healthy ageing.

Importance of ensuring the nutritional adequacy of sustainable diets for all

When transforming food systems, it is crucial to ensure that changes in dietary patterns maintain nutritional adequacy and promote health at all life stages. As we transition, policies should promote healthy, sustainable diets that are accessible, affordable, socially and culturally acceptable and adaptable to diverse dietary habits. There is no one-size-fits-all solution. The trade-offs between different dimensions of sustainability must be recognised, balancing the health and nutritional impacts of diets with their environmental footprints.

Food composition database research

Research shows that animal-based foods, particularly red meat, are beneficial for addressing nutrient deficiencies, due to their high nutrient density. Beal and Ortenzi (2022)[73] developed a global food composition database to identify primary food sources of essential micronutrients, targeting deficiencies in middle-income countries but also to help meet global malnutrition needs in low- and middle-income countries. They focused on six commonly lacking micronutrients – vitamin B12, iron, zinc, calcium, vitamin A and folate – particularly for vulnerable population groups like children, adolescents and women of reproductive age, including pregnancy and lactation. They assessed the nutritional density of foods, aiming to meet one-third of the recommended intakes for these vitamins and minerals, capping contributions at 100% of daily requirements based on an energy density of 1.3 kcal/g. The findings highlighted red meat as a leading source of priority nutrients, capable of meeting one-third of the recommended intake for selected micronutrients* with fewer calories and grams of food. Among the 36 foods analysed, beef ranked 10th, lamb 14th and pork 17th for meeting the micronutrient needs of women of reproductive age.

Red meat scored particularly high for individual micronutrients, with all meats rated ‘very high’ for zinc and vitamin B12. Beef and lamb were 'high' for iron, while pork was ‘low’. Overall, beef and lamb had ‘very high’ nutritional density, and pork was ‘high’. These findings highlight the significant role of red meat alongside other nutrient-rich foods, like seafood, fish, green leafy vegetables, eggs and dairy in addressing micronutrient gaps and reducing undernutrition, all of which are included in the UK’s Eatwell Guide recommendations.[1]

Impact of dietary transitions on micronutrient status:

A systematic review was conducted to evaluate the impact of adopting environmentally friendly diets on micronutrient levels, specifically those of concern, including vitamins A, D and B12, folate, calcium, iron, iodine and zinc. Analysing data from over 56 published studies (one RCT, 10 dietary studies, 17 dietary modelling studies and 27 diet optimisation studies), the research explored how dietary pattern changes aimed at reducing environmental impact could affect key micronutrient availability.

Only one study (the RCT) with 136 healthy adults directly assessed biomarkers in response to diet interventions that increased plant protein intake.[154] This study found significant differences in micronutrient status when replacing animal protein with 50% and 70% plant protein sources over 12 weeks.

The results in Table 30 indicate that participants in the 70% plant protein group (PP) group experienced significantly lower intakes of vitamin B12, iodine, zinc and animal-derived (haem) iron but higher total iron* and folate intake. Due to the short duration of the RCT trial, the authors recommend further research with a larger sample size and longer timeframe.

Table 30. RCT results comparing 50% plant protein to 70% plant protein intake, compared to a control group*

Nutrient	50% plant protein		70% plant protein	
	Intake	Status	Intake	Status
Iron	-	-	increased	-
Zinc	-	-	decreased	n/a
Vitamin B12	decreased	-	decreased	decreased
Iodine	decreased	decreased	decreased	decreased
Folate	-	-	increased	-

Key: *The control group included 30% plant protein intake, in the region of 70% animal to 30% plant protein intake. Source: Pellinen et al., (2022)[154], cited in Leonard et al., (2024)[153].

In reviewing the 14 dietary studies focusing on red meat-related micronutrients, researchers found a significant increase in iron intake, while most studies indicated decreases in zinc, vitamin B12 and vitamin D. The analysis of the 28 diet optimisation studies using mathematical programming yielded mixed results. While most studies successfully addressed research questions, three did not. One study in Italy showed that a diet designed to reduce greenhouse gas emissions (GHGE) did not meet the iron requirements for women.[155] The maximum iron intake achievable from the proposed diet was comparable to that of men but not suitable for women, as they require twice as much iron as men due to menstrual blood loss. The authors of the review concluded that diet optimisation studies often face challenges due to constraints imposed that are related to nutritional and environmental factors.[153] The main conclusions from the research are summarised in Table 31. Focusing solely on nutrients provided by red meat in the RCT, zinc and B12 decreased, while iron (non-haem) increased. In the dietary studies, zinc, iron and B12 decreased, and in the modelling studies, zinc and B12 decreased but iron increased (Table 31).

Table 31. Summary conclusions from Leonard et al. (2024)[153]

Research studies	Decreases in	Increases in
Randomised controlled trial	Zinc, iodine, vitamin B12	Iron*, folate
Dietary studies	Zinc, calcium, iron, vitamins B12, A and D	Folate
Dietary modelling	Zinc, calcium, vitamins B12, A and D	Iron*, folate

*The higher iron intake noted in these findings may be due to increased non-haem iron from plant-based proteins. However, the studies did not account for differences in iron bioavailability. Haem iron markers are less responsive to short-term dietary changes, highlighting the need for longer-duration studies needed to provide more comprehensive insights.

Overall, the scientific evidence suggests that adopting sustainable diet strategies may compromise micronutrient intake and status.[153] Specifically, plant-based and flexitarian diets could result in lower levels of non-haem iron, zinc and vitamin B12, as well as the contribution to vitamin D intake, compared to meat inclusive diets, putting vulnerable population groups at risk of micronutrient deficiencies. The research also highlights more robust intervention studies (such as RCTs) and standardised reporting of observational data, including key micronutrient status markers to accurately assess the impact of sustainable diets across life stages are required. It also emphasises the need to consider nutrient bioavailability, particularly for iron and zinc, especially when comparing animal and plant-based proteins.

Lastly, it is important to note that a further systematic review examined nutrient deficiencies in adults following three different dietary patterns – vegans, vegetarians and meat eaters.[52] Meat eaters consumed meat more than once a week, while vegans avoided all animal products and vegetarians excluded meat and fish. The review found common micronutrient deficits in vegan and vegetarian diets, especially vitamins B12 and D, iron and zinc, which are abundant in animal-source foods like red meat. While protein intake in vegan and vegetarian diets was lower than for meat eaters, it was within recommended intakes. However, the quality of the plant-based protein was not assessed. Vegans and vegetarian also lacked the omega-3 PUFAs, EPA and DHA, while meat eaters fell short on fibre, PUFA and ALA. Overall, all dietary patterns showed nutrient inadequacies, underscoring the importance of red meat in a healthy and balanced diet and highlighting the need for a variety of food choices to balance nutrient needs. Emphasis should be placed on following the Eatwell Guide recommendations and educating those reducing or eliminating meat on how to replace lost nutrients to prevent micronutrient deficiencies.

UK research on climate change impact modelling

The UK Climate Change Committee (CCC) recommends “a 20% reduction in all meat consumption by 2030, increasing to 35% by 2050, and a 20% reduction in dairy products by 2030.”[122] After partial acceptance of these recommendations by the Scottish government, Food Standards Scotland (FSS) tasked the University of Edinburgh with assessing the potential impacts on diet and health. Using data from the 2021 Scottish Health Survey (SHeS), researchers modelled various scenarios to evaluate how reducing meat and dairy consumption could affect nutrient intake[72] and the percentage of adults achieving Scottish dietary goals while minimising chronic disease risk.

The results indicate that 86% of Scottish adults consume meat, averaging 94 g/day (37 g of white meat, 32 g of processed meat and 26 g of red meat). Poultry was the most consumed meat (37%), followed by pork (34%), beef (25%), lamb (3%) and game (1%), with minimal gender differences. Men aged 25–34 were the highest consumers, and those in the most deprived areas tended to consume more red and red processed meat. Typical meat dishes included fried chicken, Bolognese and ham sandwiches.[72]

Meat and dairy provide essential nutrients, and reducing their intake as per the CCC recommendations increases the risk of micronutrient deficiencies, especially given poor dietary choices. However, modelling indicates that replacing them with alternatives can prevent existing nutrient insufficiencies from worsening. Initial scenarios focused on total meat reductions, but current UK guidelines recommend limiting red and red processed meat to no more than 70 g per day. SHeS data showed a downward trend with average intakes among meat consumers falling below this limit (<70g/day)[72] and aligns with the most recent NDNS report.[42] For this reason, it was suggested that research should target meat reduction in the highest red and red processed meat consumers. If these individuals reduced their daily meat intake to 70 g or less, total meat consumption could decrease by 16%, helping to meet CCC targets. The research also highlighted the need for studies to fully understand the nutritional implications, associated risks and benefits of such dietary changes on the population.

Previous research has also examined the World Cancer Research Fund (WCRF) recommendation for high meat consumers (those eating >90g/day) to limit meat intake to ≤500 g/week, which informed the 70 g/day SACN guidline.[156] The findings indicated that reducing red and processed meat consumption below 70 g increased the risk of nutrient deficiencies, particularly iron and zinc, for certain sub-groups. Intakes below the LRNI increased from 7 to 25% for zinc in males aged 19–30 years and from 40 to 48% for iron in females.[157] Socioeconomic status also significantly impacted nutrient intake, with the highest inadequacies observed in individuals classified as never working and long-term unemployed. Overall, this indicates that a universal message to reduce meat consumption may not be suitable for everyone.

Acknowledging the challenges of changing consumer behaviour, and the persistence of Scotland's dietary patterns over the past two decades, Food Standards Scotland (FSS) emphasised the need for an environment that encourages healthier food choices. This includes advocating for broader dietary objectives and promoting the Eatwell Guide, alongside initiatives to facilitate the adoption of recommended dietary practices to combat climate change. Concurrently, Nutrition Scotland launched a revised Eatwell Guide, focusing on locally sourced foods to address the cultural and economic needs of the Scottish population.[158] FSS acknowledged that the relationship between reducing meat (and dairy) consumption and benefits to human and planetary health is much more complex than previously understood.

Role of fortification in ensuring nutritional adequacy

Dietary changes to reduce meat consumption affects micronutrient intakes and public health needs. Some argue that food fortification could replace nutrients typically supplied by red meat, offering cost-effective interventions to combat vitamin and mineral deficiencies. While fortification can effectively supply essential nutrients[159], whole foods contain a complex matrix of biological compounds[160] that influences metabolism and nutrient absorption, potentially offering additional positive health benefits.[161,162]

Evidence suggests there are significant variations in fortification practices. An Australian study recently investigated fortification practices in plant-based meat analogues and found that only 12% of plant-based meat analogues were fortified with vitamin B12.[163] In the UK, research on the nutritional composition of 136 dairy and plant-based dairy alternatives revealed that 43% of plant-based milk contained no calcium and 96% lacked iodine.[164] Furthermore, 87% of cheese substitutes also had no calcium, and all yogurts and cheeses lacked iodine. While fortifying staple foods is important for addressing nutritional needs, especially in low-income countries, it should not overshadow the value of naturally nutrient-dense foods[73], nor should it be assumed that all plant-based alternatives are adequately fortified.

Encouraging a way forward

Ensuring adequate nutrition across the lifespan presents significant challenges, particularly during key life stages such as reproduction, growth, development and ageing. In the UK, notable concerns include insufficient intake of essential nutrients, including vitamin B12, iron, zinc, selenium, riboflavin, vitamin D and omega-3 fatty acids. Dietary fibre consumption falls below recommended levels, and many individuals fail to meet the guideline of consuming two portions of fish per week, with at least one being oily fish for its EPA and DHA content. Conversely, there is excessive intake of saturated fat, salt and sugar, with some people exceeding the recommended limit of 70 g of red and processed meat per day. These dietary habits can adversely affect health. Aligning UK consumption patterns with the Government's Eatwell Guide would benefit both public health and the environment.

The complexity of the current nutritional landscape is heightened by changing food consumption patterns and evolving dietary behaviours. Some consumers replace animal-based foods with plant-based alternatives, necessitating increased availability of fortified options. This places responsibility on food manufacturers, retailers and out-of-home providers to provide balanced alternatives to prevent the very real risk of nutrient deficiencies. Navigating climate change targets also presents significant challenges that could impact the nutritional adequacy of diets, particularly for vulnerable populations globally. As we pursue climate change objectives, it is vital to truly consider their implications on public health, as highlighted by existing research. Investigating how dietary adjustments can align with climate goals is still in its infancy, emphasising the need for broader research that unites experts in public health nutrition and sustainability from across the globe to address both human and planetary health needs.

Educating consumers about the importance of making informed dietary choices and a varied diet for adequate nutrient intake remains paramount, regardless of dietary pattern. Emphasising the Eatwell Guide recommendations is a good starting point.[165] Encouraging individuals with high red meat consumption to reduce their intake and incorporate more plant-rich foods can help to address human health and environmental concerns. Additionally, gradually adopting small changes, like mindful eating, meal planning and using environmental cues, can effectively shift eating habits towards healthier choices across different food consumption settings.

References

1. Public Health England (PHE). (2018). A quick guide to the government's healthy eating recommendations **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/742746/A_quick_guide_to_govt_healthy_eating_update.pdf** (Accessed 8th July 2023).
2. Van Elswyk, M.E., McNeill, S.H. (2014). Impact of grass/forage feeding versus grain finishing on beef nutrients and sensory quality: the U.S. experience. Meat Science, 96(1): 535–540.
3. Davis, H., Magistrali, A., Butler G. et al. (2022). Nutritional benefits from fatty acids in organic and grass-fed beef. Foods, 11(5): 646.
4. Public Health England (PHE). (2021a). Composition of foods integrated dataset (CoFID). McCance and Widdowson's composition of foods integrated dataset. Available at: **https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid** (Accessed 20th July 2024).
5. Department of Health and Social Care (DHSC). (2023). Great Britain Nutrition and Health Claims Register. Available at: https://www.gov.uk/government/publications/great-britain-nutrition-and-health-claims-nhc-register (Accessed 23rd October 2023).
6. European Commission (EC). (2023). EU Register of Health Claims. Available at: **https://ec.europa.eu/food/food-feed-portal/screen/health-claims/eu-register** (Accessed 23rd October, 2023).
7. Department of Health. (1991). Dietary Reference Values for Food, Energy and Nutrients for the United Kingdom, The Stationery Office (TSO). Available at: **https://assets.publishing.service.gov.uk/media/5bab98f7ed915d2bb2f56367/Dietary_Reference_Values_for_Food_Energy_and_Nutrients_for_the_United_Kingdom__1991_.pdf** (Accessed 19th November 2023).
8. Spiro, A., Hill, Z. and Stanner, S. (2024) Meat and the future of sustainable diets—Challenges and opportunities. Nutrition Bulletin, 49, 572–598. Available from: **https://doi.org/10.1111/nbu.12713**
9. Wu, G. (2009). Amino acids: metabolism, functions, and nutrition. Amino Acids, 37(1): 1–17.
10. Wyness, L., Weichselbaum, E., O'Connor, A. et al. (2011). Red meat in the diet: an update. Nutrition Bulletin, 36(1): 34-77.
11. Melina, V., Craig, W., Levin, S. (2016). Position of the Academy of Nutrition and Dietetics: vegetarian diets. Journal of the Academy of Nutrition and Dietetics, 116(12): 1970-1980.
12. Xiao, F., Guo, F. (2022). Impacts of essential amino acids on energy balance. Molecular Metabolism, 57: 101393.
13. Jäger, R., Kerksick, C.M., Campbell, B.I. et al. (2017). International Society of Sports Nutrition Position Stand: protein and exercise. Journal of the International Society of Sports Nutrition, 14(1): 20.
14. Witard, O.C., Wardle, S.L., Macnaughton, L.S. et al. (2016). Protein considerations for optimising skeletal muscle mass in healthy young and older adults. Nutrients, 8(4): 181.
15. Zaromskyte, G., Prokopidis, K., Ioannidis, T. et al. (2021). Evaluating the leucine trigger hypothesis to explain the post-prandial regulation of muscle protein synthesis in young and older adults: a systematic review. Frontiers in Nutrition, 8(685165).
16. Phillips, S.M., Martinson, W. (2019). Nutrient-rich, high-quality, protein-containing dairy foods in combination with exercise in aging persons to mitigate sarcopenia. Nutrition Reviews, 77(4): 216-229.
17. Wolfe, R.R. (2006). The underappreciated role of muscle in health and disease. American Journal of Clinical Nutrition, 84(3): 475-482.

18. Kaspy, M.S., Hannaian, S.J., Bell, Z.W. et al. (2023). The effects of branched-chain amino acids on muscle protein synthesis, muscle protein breakdown and associated molecular signalling responses in humans: an update. Nutrition Research Reviews, Sept 8: 1-14.
19. Burd, N.A., Beals, J.W., Martinez, I.G. (2019). Food-first approach to enhance the regulation of post-exercise skeletal muscle protein synthesis and remodelling. Sports Medicine, 49(Suppl 1): 59-68.
20. Leroy, F., Cofnas, N. (2020). Should dietary guidelines recommend low red meat intake? Critical Reviews in Food Science and Nutrition, 60(16): 2763-2772.
21. Joint WHO/FAO/UNU Expert Consultation. (2007). Protein and amino acid requirements in human nutrition. World Health Organization Technical Report Series 935: 1-265. Geneva. FAO/WHO/UNU.
22. Kohlmeire, M. (2003). Amino acids and nitrogen compounds. Nutrient Metabolism: A volume in Food Science & Technology, Chapter 8, pp. 244-256. Academic Press. Available at: https://doi.org/10.1016/B978-0-12-417762-8.X5000-5 (Accessed 31st July 2024).
23. Derbyshire, E., Higgs, J., Feeney, M.J. et al. (2023). Believe it or 'nut': why it is time to set the record straight on nut protein quality: pistachio (Pistacia vera L.) focus. Nutrients, 15(9): 2158. **https://doi.org/10.3390/nu15092158**
24. Beef and Lamb New Zealand (BLNZ). (2022). Protein quality – the nutritional advantage of animal-sourced foods. Available at: **https://www.beeflambnz.co.nz/protein-quality-report** (Accessed 31st July 2024).
25. WHO Technical Report Series. (2007). Protein and amino acid requirements in human nutrition: report of a Joint WHO/ FAO/UNU expert consultation.
26. Purchas, R.W., Wilkinson, B.W.P. (2013). The concentration of selected nutrients in New Zealand beef and lamb cuts and offal. 2nd edition. Massey University Institute of Food, Nutrition and Human Health.
27. Kalman, D. (2014). Amino acid composition of an organic brown rice protein concentrate and isolate compared to soy and whey concentrates and isolates. Foods, 3(3), 394-402.
28. Gorissen, S., Crombag, J., Senden, J. et al. (2018). Protein content and amino acid composition of commercially available plant-based protein isolates. Amino Acids, 50(12): 1685-1695.
29. Jenabe, M., Sabaté, J., Slimani, N. et al. (2006). Consumption and portion sizes of tree nuts, peanuts and seeds in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohorts from 10 European countries. The British Journal of Nutrition, 96(Suppl 2): S12-23.
30. Schmidt, J.A., Rinaldi S, Scalbert A. et al. (2016). Plasma concentrations and intakes of amino acids in male meat-eaters, fish-eaters, vegetarians and vegans: a cross-sectional analysis in the EPIC-Oxford cohort. European Journal of Clinical Nutrition, 70(3): 306-312.
31. Parikh, P., Semba, R., Manary, M. et al. (2022) Animal source foods, rich in essential amino acids, are important for linear growth and development of young children in low- and middle-income countries. Maternal and Child Nutrition, 18(1): e13264.
32. Tome, D. (2013). Digestibility issues of vegetable versus animal proteins: Protein and amino acid requirements–functional aspects. Food and Nutrition Bulletin, 34(2): 272–274.
33. Tome, D. (2012). Criteria and markers for protein quality assessment—A review. British Journal of Nutrition, 108(Suppl. 2): S222–S229.
34. Schaafsma, G. (2000). The protein digestibility-corrected amino acid score. The Journal of Nutrition, 130(7): 1865S–1867S.
35. Food and Agricultural Organization of the United Nations (FAO), (2013). Dietary protein quality evaluation in human nutrition. Report of an FAQ Expert Consultation. FAO Food and Nutrition Paper 92: 1-66. Available at: **https://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf** (Accessed 30th November 2023).
36. Hodgkinson, S.M., Montoya, C.A., Scholten, P.T. et al. (2018). Cooking conditions affect the true ileal digestible amino acid content and Digestible Indispensable Amino Acid Score (DIAAS) of bovine meat as determined in pigs. The Journal of Nutrition, 148(10): 1564–1569.
37. Bailey, H.M., Stein, H.H. (2019). Can the digestible indispensable amino acid score methodology decrease protein malnutrition. Animal Frontiers, 9(4): 18-23.
38. Hybu Cig Cymru – Meat Promotion Wales (HCC). (2023). Welsh Lamb Meat Quality Project, HCC/Agri Food Biosciences Unit. Available at: https://meatpromotion.wales/en/industry-projects/red-meat-development-programme/cynllun-safon-bwyta-cig-oen/results (Accessed 12th December 2023).
39. Pinckaers, P.J., Domić, J., Petrick, H.L. et al. (2023). Higher muscle protein synthesis rates following ingestion of an omnivorous meal compared with an isocaloric and isonitrogenous vegan meal in healthy, older adults. The Journal of Nutrition, 154(7): 2120-2132.
40. Wu, G. (2020). Important roles of dietary taurine, creatine, carnosine, anserine and 4-hydroxyproline in human nutrition and health. Amino Acids, 52(3): 329-360.
41. Public Health England (PHE). (2016). Government dietary recommendations – government recommendations for energy and nutrients for males and females aged 1-18 years and 19+ years. Available at:

https://assets.publishing.service.gov.uk/media/5a749fece5274a44083b82d8/government_dietary_recommendations.pdf (Accessed 4th January 2024).
42. Public Health England (PHE). (2020). NDNS: results from years 9 to 11 (2016 to 2017 and 2018 to 2019). **https://www.gov.uk/government/statistics/ndns-results-from-years-9-to-11-2016-to-2017-and-2018-to-2019** (Accessed 14th July 2023).
43. Arnesen, E.K., Thorisdottir, B., Lamberg-Allardt, C. et al (2022). Protein intake in children and growth and risk of overweight or obesity: a systematic review and meta-analysis. Food & Nutrition Research, 66.
44. United Nations Children's Fund (UNICEF), World Health Organization (WHO), International Bank for Reconstruction and Development/The World Bank. (2023). Levels and trends in child malnutrition: UNICEF / WHO / World Bank Group Joint Child Malnutrition Estimates: Key findings of the 2023 edition. New York: UNICEF and WHO. Available at: **https://data.unicef.org/resources/jme-report-2023** (Accessed 14th August 2024).
45. Food and Agriculture Organisation (FAO). (2024). FAO Knowledge Repository. Available at: https://openknowledge.fao.org/home (Accessed 15th August 2024).
46. Mariotti, F., Gardner, C.D. (2019). Dietary protein and amino acids in vegetarian diets: a review. Nutrients, 11(11): 2661.
47. Trussell Trust. (2024). Hunger in the UK. Available at: **https://www.trusselltrust.org/wp-content/uploads/sites/2/2023/08/2023-The-Trussell-Trust-Hunger-in-the-UK-report-web-updated-10Aug23.pdf** (Accessed 8th April 2024).
48. Hanson, K.L., Connor, L.M. (2014). Food insecurity and dietary quality in US adults and children: a systematic review. American Journal of Clinical Nutrition, 100(2): 684-692.
49. Bakaloudi, D.R., Halloran, A., Rippin, H.L. et al. (2021). Intake and adequacy of the vegan diet. A systematic review of the evidence. Clinical Nutrition, 40(5): 3503-3521.
50. Bauer, J., Biolo, G., Cederholm, T. et al. (2013). Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. Journal of the American Medical Directors Association, 14(8): 542-559.
51. Marinangeli, C.P.F., Fabek, H., Ahmed, M. et al. (2021). The effect of increasing intakes of plant protein on the protein quality of Canadian diets. Applied Physiology, Nutrition and Metabolism, 46(7): 771-780.
52. Neufingerl, N., Eilander, A. (2021a). Nutrient intake and status in adults consuming plant-based diets compared to meat-eaters: a systematic review. Nutrients, 14(1): 29.
53. Forester, S.M., Jennings-Dobbs, E.M., Sathar, S.A. et al. (2023). Perspective: developing a nutrient-based framework for protein quality. The Journal of Nutrition, 153(8): 2137-2146.
54. Higgs, J. (2000). The changing nature of red meat: 20 years of improving nutritional quality. Trends in Food Science and Technology, 11(3): 85-95.
55. Scientific Advisory Committee on Nutrition (SACN). (2019). Saturated fats and health. The Stationery Office. Available at: **https://assets.publishing.service.gov.uk/media/5d1f88af40f0b609dba90ddc/SACN_report_on_saturated_fat_and_health.pdf** (Accessed 27th December 2023).
56. Wood, J.D., Enser, M., Fisher, A.V. et al. (2008). Fat deposition, fatty acid composition and meat quality: a review. Meat Science, 78(4): 343–358.
57. European Food Safety Authority (EFSA). (2017). Dietary Reference Values for nutrients: Summary Report. Available at: **https://www.efsa.europa.eu/sites/default/files/2017_09_DRVs_summary_report.pdf** (Accessed 14th August 2024).
58. Scientific Advisory Committee on Nutrition (SACN). (2004). Advice on fish consumption: benefits and risks. London, The Stationery Office.
59. British Nutrition Foundation Task Force. (2019). Cardiovascular Disease: diet, nutrition and emerging risk factors, Second Edition. Edited by Stanner, S and Coe, S. Chaired by Frayn, K. British Nutrition Foundation: London, John Wiley and Sons Ltd.
60. Mozaffarian, D., Micha, R., Wallace, S. (2010). Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: a systematic review and meta-analysis of randomized controlled trials. PLoS Medicine, 7(3): e1000252.
61. Stanner, S., Thompson, R., Buttriss, J.L. (2009). Healthy Ageing: the role of nutrition and lifestyle. British Nutrition Foundation: London, John Wiley and Sons Ltd.
62. Public Health England (PHE). (2021b). National Diet and Nutrition Survey: diet, nutrition and physical activity in 2020. A follow up study during COVID-19. Available at: **https://assets.publishing.service.gov.uk/media/614b16c8d3bf7f71919a7f47/Follow_up_stud_2020_main_report.pdf** (Accessed 14th August 2024).
63. European Food Safety Authority (EFSA). (2010). Scientific opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol. EFSA Journal, 8(3): 1461.

64. Baker, E.J., Miles, E.A., Burdge, G.C. et al. (2016). Metabolism and functional effects of plant-derived omega-3 fatty acids in humans. Progress in Lipid Research, 64: 30-56.
65. Daley, C.A., Abbott, A., Doyle, P.S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutrition Journal, 9(1): 10.
66. Ashwell, M., Hickson, M., Stanner, S. (2023). Nature of the evidence base and strengths, challenges and recommendations in the area of nutrition and health claims: a position paper from the Academy of Nutrition Sciences. British Journal of Nutrition, 130(2): 221-238.
67. National Health Service (NHS). (2023). Hospital admissions with a diagnosis of rickets and vitamin deficiency. Available at: https://digital.nhs.uk/supplementary-information/2023/hospital-admissions-with-a-diagnosis-of-rickets-and-vitamin-deficiency (Accessed 18th March 2024).
68. Scientific Advisory Committee on Nutrition (SACN). (2021). SACN statement on nutrition in older adults living in the community. Available at: **https://assets.publishing.service.gov.uk/media/6007fdc78fa8f50d8f210fb9/SACN_Nutrition_and_older_adults.pdf** (Accessed 18th of March 2024).
69. Scottish Health Survey (SHeS). (2021). Scottish Health Survey 2021. Available at: https://www.gov.scot/collections/scottish-health-survey/ (Accessed 10th April 2024).
70. National Health Service (NHS). (2024a). Symptoms – Vitamin B12 or folate deficiency anaemia. Available at: **https://www.nhs.uk/conditions/vitamin-b12-or-folate-deficiency-anaemia/symptoms/** (Accessed 13th March 2024).
71. Public Health England (PHE). (2014). National Diet and Nutrition Survey (NDNS): Results from years, 1, 2, 3 and 4 (combined) of the rolling programme (2008/2009-2011/2012). Available at: **https://assets.publishing.service.gov.uk/media/5a80dbd840f0b62302695e6d/NDNS_Y1_to_4_UK_report_executive_summary_revised_February_2017.pdf** (Accessed 18th March 2024).
72. Food Standards Scotland (FSS). (2024). Modelling the impact of reductions in meat and dairy consumption on nutrient intakes and disease risk. Available at: **https://www.foodstandards.gov.scot/downloads/Summary_briefing_-_Modelling_the_impact_of_reductions_in_meat_and_dairy_.pdf** (Accessed 13th March 2024).
73. Beal, T., Ortenzi, F. (2022). Priority micronutrient density in foods. Frontiers in Nutrition, 9: 806566.
74. British Dietetic Association (BDA). (2024). Vegetarian, vegan and plant-based diet. Available at: **https://www.bda.uk.com/resource/vegetarian-vegan-plant-based-diet.html** (Accessed 27th March 2024).
75. Scientific Advisory Committee on Nutrition (SACN). (2016). Vitamin D and health. Available at: **https://assets.publishing.service.gov.uk/media/5a804e36ed915d74e622dafa/SACN_Vitamin_D_and_Health_report.pdf** (Accessed 7th of March 2024).
76. Larson-Meyer DE, Ingold BC, Fensterseifer SR, Austin KJ, Wechsler PJ, Hollis BW, Makowski AJ, Alexander BM (2017). Sun exposure in pigs increases the vitamin D nutritional quality of pork. PLoS One. 12(11): e0187877
77. Neill, H.R., Gill, C.I.R., McDonald, E.J, McMurray R, McRoberts, WC. Loy R, White A, Little R, Muns R, Rosbotham EJ, O'Neill U, Smyth S, Pourshahidi LK. (2023). Improving vitamin D content in pork meat by UVB biofortification. Meat Science Volume 199,
78. Scientific Advisory Committee on Nutrition (SACN). (2010). Iron and health. Available at: **https://assets.publishing.service.gov.uk/media/5a7df3dd40f0b62305b7fd53/SACN_Iron_and_Health_Report.pdf** (Accessed 26th October 2023).
79. Fairweather-Tait, S. (2023). The role of meat in iron nutrition of vulnerable groups of the UK population. Frontiers in Animal Science, 4: 1142252.
80. Fairweather-Tait, S., Sharp, P. (2021). Iron. Advances in Food and Nutrition Research, 96: 219–250.
81. Food Systems Dashboard. (2024). Available at: **https://www.foodsystemsdashboard.org/indicators/outcomes/nutritional-status/anemia-in-women-15-49-years/map** (Accessed 15th August 2024).
82. National Health Service (NHS). (2024b). Iron deficiency anaemia. Available at: **https://www.nhs.uk/conditions/iron-deficiency-anaemia/.** (Accessed 19th March 2024).
83. Zimmerman, M.B., Hurrell, R.F. (2007). Nutritional iron deficiency. Lancet, 37(9586): 511-520.
84. Lombardi-Boccia, G., Martinez-Dominguez, B., Aguzzi, A. (2002). Total heme and non-heme iron in raw and cooked meats. Journal of Food Science, 67(5): 1738-1741.
85. Consalez, F., Ahern, M., Andersen, P. et al. (2022). The effect of the meat factor in animal-source foods on micronutrient absorption: a scoping review. Advances in Nutrition, 13(6): 2305-2315.
86. Hurrell, R., Egli, I. (2010). Iron bioavailability and dietary reference values. American Journal of Clinical Nutrition, 91: 1461-1467.
87. New Zealand Institute for Plant and Food Research Limited and Ministry of Health. (2021). The concise New Zealand food composition tables. 14th Edition. Wellington: New Zealand.

88. European Food Safety Authority (EFSA) Panel on Dietetic Products, Nutrition and Allergies (NDA). (2015). Scientific opinion on dietary reference values for iron. EFSA Journal, 13(10): 4254.
89. Carpenter, C.E., Mahoney, A.W. (1992). Contributions of heme and nonheme iron to human nutrition. Critical Reviews in Food Science and Nutrition, 31(4): 333-367.
90. Hallberg, L. (1983). Iron requirements and bioavailability of dietary iron. British Journal of Nutrition, 44: 223-244
91. Cook, J.D., Monsen, E.R. (1977). Vitamin C, the common cold and iron absorption. American Journal of Clinical Nutrition, 30(2): 235-241.
92. Hallberg, L., Brune, M., Rossander, L. (1989). The role of vitamin C in iron absorption. International Journal of Vitamin and Nutrition Supplement Research, 30: 103–108.
93. Sarwar, G.G., Wu Xiao, C., Cockell, K.A. (2012). Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. British Journal of Nutrition, 108(Suppl 2): S315-332.
94. Schönfeldt, H.C., Hall, N.G. (2011). Determining iron bio-availability with a constant heme iron value. Journal of Food Composition Analysis, 24(4): 738-740.
95. Amin, A., Petersen, I.L., Malmberg, C. et al. (2022). Perspective on the effect of protein extraction method on the anti-nutritional factor (ANF) content in seeds. ACS Food Science and Technology, 2(4): 604-612.
96. Gibson, R.S., Bailey, K.B., Gibbs, M. et al. (2010). A review of phytate, iron, zinc, and calcium concentrations in plant- based complementary foods used in low-income countries and implications for bioavailability. Food and Nutrition Bulletin, 31(Suppl 2): S134–S146.
97. Layrisse, M., Martínez-Torres, C., Renzy, M. et al. (1975). Ferritin iron absorption in man. Blood, 45(5): 689–698.
98. Cook, J.D. (1990). Adaptation in iron metabolism. American Journal of Clinical Nutrition, 51(2): 301–308.
99. Gandemer, G., Scislowski, V., Portanguen, S. et al. (2020). The impact of cooking of beef on the supply of heme and non-heme iron for humans. Food and Nutrition Sciences, 11(7): 629–648.
100. Cross, A.J., Harnly, J.M., Ferrucci, L.M. (2012). Developing a heme iron database for meats according to meat type, cooking method and doneness level. Food and Nutrition Sciences, 3(7): 905–913.
101. Leroy, F., Heinrich, F., Lee, M.R.F. et al. (2023). Meat matters: making the case for a valuable food in a hostile environment. Italian Journal of Animal Science, 22(1): 885-897.
102. Knez, M., Stangoulis, J.C.R. (2023). Dietary Zn deficiency, the current situation and potential solutions. Nutrition Research Reviews, 36(2): 199-215.
103. Wessells, K.R., Brown, K.H. (2012). Estimating the global prevalence of zinc deficiency: results based on zinc availability in national food supplies and the prevalence of stunting. PLoS One, 7(11): e50568.
104. Sharma, A., Patni, B., Shankhdhar, D. et al. (2013). Zinc – an indispensable micronutrient. Physiology and Molecular Biology of Plants, 19(1): 11–20.
105. AO/IAEA/WHO. (2002). Trace elements in human nutrition and health. Geneva: World Health Organization.
106. Shankar, A.H., Prasad, A.S. (1998). Zinc and immune function: the biological basis of altered resistance to infection. American Journal of Clinical Nutrition, 68(Suppl.2): 447s–463s.
107. Prasad, A.S. (2003). Zinc deficiency: has been known of for 40 years but ignored by global health organisations. British Medical Journal, 326(7386): 409–410.
108. Knoell, D.L., Julian, M.W., Bao, S. et al. (2009). Zinc deficiency increases organ damage and mortality in a murine model of polymicrobial sepsis. Critical Care Medicine, 37(4): 1380–1388.
109. Picado, C., Deulofeu, R., Lleonart, R. et al. (2001). Dietary micronutrients/antioxidants and their relationship with bronchial asthma severity. Allergy, 56(1): 43–49.
110. Victora, C.G., Christian, P., Vidaletti, L.P. et al. (2021). Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. Lancet, 397(10282): 1388–1399.
111. Prasad, A.S. (2012). Discovery of human zinc deficiency: 50 years later. Journal of Trace Elements in Medicine and Biology, 26(2-3): 66–69.
112. Lonnerdal, B. (2000). Dietary factors influencing zinc absorption. Journal of Nutrition, 130(5S Suppl): 1378s–1383s.
113. Gibson, R.S. (2006). Zinc: The missing link in combating micronutrient malnutrition in developing countries. Proceedings of the Nutrition Society, 65(1): 51-60.
114. Roohani, N., Hurrell, R., Kelishadi, R. et al. (2013). Zinc and its importance for human health: an integrative review. Journal of Research in Medical Sciences, 18(2): 144–157.
115. Beiseigel, J.M., Klevay, L.M., Hunt, J.R. (2006). Healthy postmenopausal women adapt to reduce zinc absorption in response to zinc supplementation. The FASEB Journal, 20(5): A985.
116. Hunt, J.R., Beiseigel, J.M., Johnson, L.K. (2008). Adaptation in human zinc absorption as influenced by dietary zinc and bioavailability. American Journal of Clinical Nutrition, 87(5): 1336–1345.

117. Prasad, A.S. (1984). Discovery and importance of zinc in human nutrition. Federation Proceedings, 43(13): 2829–2834.
118. Sandstrom, B. (1997). Bioavailability of zinc. European Journal of Clinical Nutrition, 51(Suppl. 1): S17–S19.
119. Haase, H., Rink, L. (2014). Multiple impacts of zinc on immune function. Metallomics, 6(7): 1175–1180.
120. Hambidge, K.M., Abebe, Y., Gibson, R.S. et al. (2006). Zinc absorption during late pregnancy in rural southern Ethiopia. American Journal of Clinical Nutrition, 84(5): 1102–1106.
121. Schlemmer, U., Frolich, W., Prieto, R.M. et al. (2009). Phytate in foods and significance for humans: food sources, intake, processing, bioavailability, protective role and analysis. Molecular Nutrition and Food Research, 53(Suppl 2): S330–S375.
122. Climate Change Committee (CCC). (2020). The sixth carbon budget – the UK's path to net zero. December, 2020. London, Committee on Climate Change.
123. FAO/WHO. (2004). Human vitamin and mineral requirements: report of a joint FAO/WHO expert consultation. Rome: FAO/WHO.
124. Scientific Advisory Committee on Nutrition (SACN). (2024). 71st Meeting, 14th March 2024, Final Minutes. Available at: https://app.box.com/s/ivrivaemf7fgeo9a17xdmv167c4uvteu/file/1599425046840 (Accessed 15th August 2024).
125. Mistry, H.D., Broughton, F.B., Redman, C.W.G. (2012). Selenium in reproductive health. American Journal Obstetrics and Gynecology, 206(1): 21-30.
126. Shreenath, A.P., Hashmi, M.F., Dooley, J. (2023). Selenium Deficiency. [Updated 2023 Oct 29]. In: StatPearls [Internet]. StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK482260/ (Accessed 25th March 2024).
127. Food and Agricultural Organization of the United Nations (FAO). (2023b). Contribution of terrestrial animal source food to healthy diets for improved nutrition and health outcomes: an evidence and policy overview on the state of knowledge and gaps. Rome, FAO. Available at: https://www.fao.org/3/cc3912en/cc3912en.pdf (Accessed 1st December 2023).
128. National Health Service (NHS). (2024c). Have a healthy diet in pregnancy. Available at: https://www.nhs.uk/pregnancy/keeping-well/have-a-healthy-diet/ (Accessed 15th January 2024).
129. Scientific Committee for Food. (1993). Reports of the Scientific Committee for Food (Thirty-first series). Nutrient and energy intakes for the European Community. Available at: https://food.ec.europa.eu/horizontal-topics/expert-groups/scientific-committees/scientific-committee-food-archive_en (Accessed 16th August 2024).
130. Food and Agriculture Organization and the World Health Organization. (FAO/WHO). (2002). Human vitamin and mineral requirements. Report of a joint FAO/WHO expert consultation Bangkok, Thailand. Rome: WHO/FAO.
131. Institute of Medicine (IOM). (2001). Institute of Medicine panel on micronutrients, Dietary Reference Intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. National Academies Press, Washington, DC.
132. Dror, D.K., Allen, L.H. (2018). Overview of nutrients in human milk. Advances in Nutrition, 9(Suppl.1): 278S-294S.
133. Obbagy, J.E., English, L.K., Psota, T.L. et al. (2019). Complementary feeding and micronutrient status: a systematic review. American Journal of Clinical Nutrition, 109(Suppl.7): 852S-871S.
134. Godfrey, K.M., Titcombe, P., El-Heis, S. et al. (2023). Maternal B-vitamin and vitamin D status before, during, and after pregnancy and the influence of supplementation preconception and during pregnancy: prespecified secondary analysis of the NiPPeR double-blind randomized controlled trial. PLoS Medicine, 20(12): e1004260.
135. Beal, T., Otenzi, F., Fanzo, J. (2023). Estimated micronutrient shortfalls of the EAT-Lancet planetary health diet. The Lancet Planetary Health, 7(3): e233-237.
136. Stevens, G.A., Beal, T., Mbuya, M.N.N. et al. (2022). Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys. The Lancet Global Health, 10(11): e1590-e1599.
137. Asare, H., Rosi, A., Faber, M. et al. (2022). Animal-source foods as a suitable complementary food for improved physical growth in 6 to 24-month-old children in low- and middle-income countries: a systematic review and meta-analysis of randomised controlled trials. British Journal of Nutrition, 128(12): 2453-2463.
138. Eaton, J.C., Rothpletz-Puglia, P., Dreker, M.R. et al. (2019). Effectiveness of provision of animal-source foods for supporting optimal growth and development in children 6–59 months of age. The Cochrane database of systematic reviews, 2(2): CD012818.
139. An, R., Ji, M., Zhang, S. et al. (2019). Systematic review of the effect of dietary meat on cognitive function and dementia risk in the elderly. Public Health Nutrition, 22(11): 2171-2178.

140. Gewa, C.A., Murphy, S.P., Neumann, C.G. (2009). A comparison of self-reported morbidity and health status of school-age children from a meat-supplemented, a milk-supplemented, and a control feeding intervention study. European Journal of Clinical Nutrition, 63(6): 816-822.
141. Hulett, J.L., Weiss, R.E., Bwibo, N.O. et al. (2014). Animal source foods have a positive impact on the primary school test scores of Kenyan schoolchildren in a cluster-randomized, controlled feeding intervention trial. The Journal of Nutrition, 144(5): 662-669.
142. Neumann, C.G., Murphy, S.P., Gewa, C. et al. (2007). Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. The Journal of Nutrition, 137(4): 1119-1123.
143. Whaley, S.E., Sigman, M., Neumann, C. et al. (2003). The impact of dietary intervention on the cognitive development of Kenyan school children. The Journal of Nutrition, 133(11 Suppl. 2): 3965S-3971S.
144. Hepsomali, P., Groegar, J.A. (2021). Diet and general cognitive ability in the UK Biobank dataset. Scientific Reports, 11(1): 11786.
145. Neumann, C., Harris, D.M., Rogers, L.M. (2002). Contribution of animal source foods in improving diet quality and function in children in the developing world. Nutrition Research, 22(1-2): 193–220.
146. Mei, Z., Addo, O.Y., Jefferds, M.E. et al. (2021). Physiologically based serum ferritin thresholds for iron deficiency in children and non-pregnant women: a US National Health and Nutrition Examination Surveys (NHANES) serial cross- sectional study. Lancet Haematology, 8: e572–e582.
147. Sun, H., Weaver, C.M. (2021). Decreased iron intake parallels rising iron deficiency anemia and related mortality rates in the US population. Journal of Nutrition, 151(7): 1947–1955.
148. Age UK. (2024). Malnutrition. Available at: https://www.ageuk.org.uk/information-advice/health-wellbeing/conditions-illnesses/malnutrition/ (Accessed 4th April 2024).
149. Malnutrition Task Force. (2021). State of the Nation. Older people and malnutrition in the UK today. Available at: https://www.malnutritiontaskforce.org.uk/sites/default/files/2021-10/State%20of%20the%20Nation%202020%20F%20revise.pdf (Accessed 4th April 2024).
150. British Association for Parenteral and Enteral Nutrition (BAPEN). (2022). Malnutrition and nutritional care survey in adults. Available at: https://www.bapen.org.uk/pdfs/reports/mag/national-survey-of-malnutrition-and-nutritional-care-2022.pdf (Accessed 6th April 2024).
151. Coelho-Junior, H.J., Calvani, R., Picca, A. et al. (2022). Protein intake and frailty in older adults: a systematic review and meta-analysis of observational studies. Nutrients, 14(13): 2767.
152. Granic, A., Dismore, L., Hurst, C. et al. (2020). Myoprotective whole foods, muscle health and sarcopenia: a systematic review of observational and intervention studies in older adults. Nutrients, 12(8): 2257.
153. Leonard, U.M., Leydon, C.L., Arranz, E. et al. (2024). Impact of consuming an environmentally protective diet on micronutrients: a systematic literature review. American Journal of Clinical Nutrition, 119(4): 927-948.
154. Pellinen, T., Päivärinta, E., Isotalo, J. et al. (2022). Replacing dietary animal-source proteins with plant-source proteins changes dietary intake and status of vitamins and minerals in healthy adults: a 12-week randomized controlled trial. European Journal of Nutrition, 61(3): 1391-1404.
155. Ferrari, M., Benvenuti, L., Rossi, L. et al. (2020). Could dietary goals and climate change mitigation be achieved through optimized diet? The experience of modelling the national food consumption data in Italy. Frontiers in Nutrition, 7: 48.
156. World Cancer Research Fund (WCRF). (2023). Limit red meat and avoid processed meat. Available at: https://www.wcrf.org/diet-activity-and-cancer/cancer-prevention-recommendations/limit-red-and-processed-meat/ (Accessed 1st Aug 2023).
157. James, W.H.M., Lomax, N., Birkin, M. et al. (2022). Targeted policy intervention for reducing red meat consumption: conflicts and trade-offs. BMC Nutrition, 8(1): 80.
158. Nutrition Scotland (2024) Scottish Eatwell Guide: Showcasing how Scottish produce fits into a balanced diet. Available at: https://www.nutritionscotland.org/resources/scottish-eatwell-guide/ (Accessed 7th April 2024).
159. Osendarp, S.J.M., Martinez, H., Garrett, G.S. et al. (2018). Large-scale food fortification and biofortification in low- and middle-income countries: a review of programs, trends, challenges, and evidence gaps. Food and Nutrition Bulletin, 39(2): 315–331.
160. Plumb, J., Pigat, S., Bompola, F. et al. (2017). eBASIS (Bioactive Substances in Food Information Systems) and bioactive intakes: major updates of the bioactive compound composition and beneficial bioeffects database and the development of a probabilistic model to assess intakes in Europe. Nutrients, 9(4): 320.
161. Jacobs, D.R., Tapsell, L.C. (2007). Food, not nutrients, is the fundamental unit in nutrition. Nutrition Reviews, 65(10): 439-450.
162. Aguilera, J.M. (2019). The food matrix: implications in processing, nutrition and health. Critical Reviews in Food Science and Nutrition, 59(22): 3612-3629.
163. Melville, H., Shahid, M., Gaines, A. et al. (2023). The nutritional profile of plant-based meat analogues available for sale in Australia. Nutrition and Dietetics, 80(2): 211-222.

164. Clegg, M.E., Tarrado Ribes, A., Reynolds, R. et al. (2021). A comparative assessment of the nutritional composition of dairy and plant-based dairy alternatives available for sale in the UK and the implications for consumers' dietary intakes. Food Research International, 148: 110586.
165. Steenson, S., Buttriss, J.L. (2021). Healthier and more sustainable diets: what changes are needed in high-income countries? Nutrition Bulletin. 46(3): 279-309.
166. Enser, M., Hallett, K., Hewitt, B. Fursey, G.A.J., Wood, J.D. (1996) Fatty acid content and composition of english beef, lamb and pork at retail. Meat Science, 42(4): 443-456

4. Role of red meat on health and non-communicable disease risk

Summary points:

- The World Health Organization (WHO) highlights that a healthy diet protects against malnutrition and non-communicable diseases (NCDs), including diabetes, heart disease, stroke and cancer. In the UK, rising obesity rates, unhealthy food choices, sedentary lifestyles and health inequalities are major contributors to NCD rates. Adopting a diet that aligns with the Eatwell Guide, which includes at least five portions of fruits and vegetables daily and 30 g of fibre, can play a significant role in reducing the risk of NCDs
- The Government recommends a maximum of 500 g per week (70 g per day cooked weight) of red and processed meat. Those consuming more than 90 g per day should try to reduce it to 70 g or less. On average, UK adults consume 63 g per day, with higher intakes among men and individuals living in deprived areas
- A universal message to eat 'less meat' overlooks individual consumption and the nutritional needs of vulnerable groups, such as children, pregnant women and older adults. Following the Eatwell Guide ensures that reducing meat intake does not compromise micronutrient levels. Balancing red meat consumption with a healthier overall diet is crucial for disease prevention and better nutrition
- Understanding the hierarchy of evidence is important when assessing the link between red meat consumption and NCD risk. Observational studies offer the lowest evidence level, while randomised controlled trials (RCTs) provide stronger cause-and-effect insights. Systematic reviews and meta-analyses of primary research offers even stronger evidence and umbrella reviews which compile data from systematic reviews and meta-analyses represent one of the highest levels of scientific evidence. This report analysed secondary research from systematic reviews and meta-analyses of prospective cohort studies and RCTs, along with tertiary evidence from umbrella reviews where available
- Systematic reviews and meta-analyses of observational studies suggest a link between red and processed meat consumption and increased risks of colorectal cancer, cardiovascular disease (CVD) and type 2 diabetes (T2D). However, stronger evidence from RCTs often does not support a strong causal relationship. Despite mixed evidence, UK health guidelines recommend limiting red and processed meat intake to mitigate potential health risks
- Limit red and processed meat consumption to no more than 70 g per day. Cancer guidelines from the World Cancer Research Fund and the American Institute of Cancer Research (WCRF/AICR) have been consistent since the last update in 2018
- Early research in 2007 suggested a "convincing" association between red meat consumption and colorectal cancer, but evidence in 2017 downgraded red meat to a "probable" cause, while processed meat remained a "convincing" cause.
- Cardiovascular disease (CVD) is the leading cause of death worldwide, accounting for 68,000 deaths annually in the UK. Evidence from systematic reviews and meta-analyses of observational studies is mixed, indicating a stronger association between processed meat and CVD than unprocessed red meat, but overall

risk increases are small. RCTs highlight uncertainties in the causal relationship between red meat consumption and CVD risk, suggesting that observational studies may overestimate the impact

- Reducing red meat consumption by three servings (total 360 g) per week had little effect on cardiometabolic outcomes related to CVD or stroke, with low certainty of evidence, similar to cancer outcomes. One serving of red meat is equivalent to 120 g of unprocessed meat or 50 g of processed meat (or a 100 g mix). This raises questions about global health recommendations to reduce meat intake. Replacing meat with high-quality plant proteins may produce different results, but the evidence remains uncertain, requiring further research for clearer conclusions
- Diabetes affects over 4.3 million people in the UK, with 90% having T2D. Major contributing factors include poor diet, lack of physical activity and high obesity rates. Based on findings from three observational studies, Diabetes UK guidelines recommend reducing red and processed meat intake due to its association with an increased T2D risk
- Systematic reviews and meta-analyses of observational studies indicate a stronger link between processed meat and T2D than unprocessed red meat, with modest reductions in intake associated with lower risk. However, systematic reviews and meta-analyses of RCTs do not provide sufficient evidence for a causal relationship. One meta-analysis found that higher red meat intake does not significantly impact glycaemic control or inflammation in adults at risk of T2D, while another reported neutral effects for consumption over 110 g per day. Standardised definitions and more rigorous methodologies are needed to clarify the meat intake and T2D relationship for the dietary recommendations for prevention and management of T2D
- Processed meat is generally associated with higher NCD risks than unprocessed red meat. Confusion in research arises from the inappropriate categorisation of these meats. Clear distinctions and definitions are essential for informed dietary recommendations
- Critics of research linking red meat to health risks argue that moderate consumption may be less harmful than believed. Experts call for well-designed long-term RCTs to better assess the meat's impact on NCDs. Robust and high-quality studies are essential for developing reliable dietary guidelines and health recommendations
- Red meat purchases in the UK are declining, while white meat sales are increasing. However, there is a concerning increase in high-calorie, saturated-fat and salt-rich ready meals and convenience foods. Additionally, higher processed meat consumption is linked to unhealthy behaviours, including lower fruit and vegetable intake, higher BMI, smoking and physical inactivity, all of which increase NCD risk
- Addressing NCD risks requires a holistic approach that goes beyond reducing meat consumption. Factors such as poor diet choices, low physical activity, mental health issues, environmental conditions and healthcare access contribute to growing health inequalities. Government intervention and comprehensive public health strategies are essential for improving overall health and mitigating NCD risks
- In the absence of broader UK research, Food Standards Scotland modelled different meat reduction scenarios to align with Scottish Dietary Goals and the Climate Change Committee (CCC) target of a 20% reduction in meat consumption by 2030. The findings indicated that if high consumers of red and processed meat (over 90 g/day) reduce their intake to 70 g/day, it would lower total meat consumption by 16% and improve health outcomes like BMI, cardiovascular health and T2D rates. However, further reductions could negatively impact micronutrient levels, particularly in vulnerable groups already nutritionally compromised. Targeting higher meat consumers offers a viable solution to meeting both planetary and health needs

- Given uncertainties about the role of red meat in NCD risk amid poor dietary habits and rising obesity rates, caution is advised. Strategies should focus on guiding high meat consumers (>90 g/day) towards balanced diets according to the Eatwell Guide

Introduction

Food consumption and dietary preferences are key to our health, influencing both risks and benefits. Our dietary choices significantly affect the risk of non-communicable diseases (NCDs) and can promote health and longevity. The World Health Organization (WHO) states that a healthy diet protects against malnutrition and NCDs, including diabetes, heart disease, stroke and cancer.[1]

Current health-related statistics

In the UK, a large portion of the population is overweight or obese, with 26% of adults in England classified as obese and 38% overweight. Men are more affected than women (69% vs. 59%), particularly those aged 45–74.[2] This obesity epidemic imposes a substantial financial burden on the National Health Service (NHS), costing approximately £6.5 billion annually.[3]

Obesity increases the risk of NCDs, such as cardiovascular disease (CVD), type 2 diabetes (T2D), and certain cancers.[4] It is a leading cause of CVD, and it significantly contributes to T2D risk,[5] which rises significantly with increases in body mass index (BMI). Consequently, the global rise in obesity has corresponded with the increased prevalence of T2D.[6] Furthermore, obesity is the second leading cause of cancer,[3] particularly colorectal cancer,[7] emphasising the importance of a healthy, balanced diet and regular physical activity.

It is estimated that 7.6 million individuals are living with circulatory diseases in the UK and over half the population are predicted to develop a cardiovascular condition in their lifetime.[8] Additionally, there are 3 million cancer patients,[9] and over 5 million people diagnosed with diabetes in the UK.[10] Moreover, 37% of adults do not meet physical activity recommendations,[8] which is implicated with weight gain and obesity, increasing the risk of T2D and CVD.

Malnutrition is defined as inadequate dietary intake to maintain an individual's health and currently affects one in ten UK adults aged over 65.[11] However, it can manifest as undernutrition, characterised by muscle wasting, stunting and micronutrient deficiencies, or overnutrition, leading to being overweight or obese, known as the double burden of malnutrition.[12] Malnutrition associated with overnutrition results from high consumption of calorie-dense foods, causing weight gain and diminishing intakes of key nutrients.[13] Food insecurity, linked closely to malnutrition, entails cutting back on the quality or quantity of food due to financial difficulties. Food insecurity is a pressing concern in the UK, as 11.3 million individuals experienced it between 2021 and 2022.[14] The current cost-of-living crisis has amplified this further, whereby increasing numbers of people are using food banks to survive.[15] Health inequalities are widening, with less well-off individuals having a poor-quality diet, leading to poor micronutrient intake and status[16] and increased risk of weight gain and obesity[17, 18] and the subsequent development of T2D[19,20] and CVD.[21]

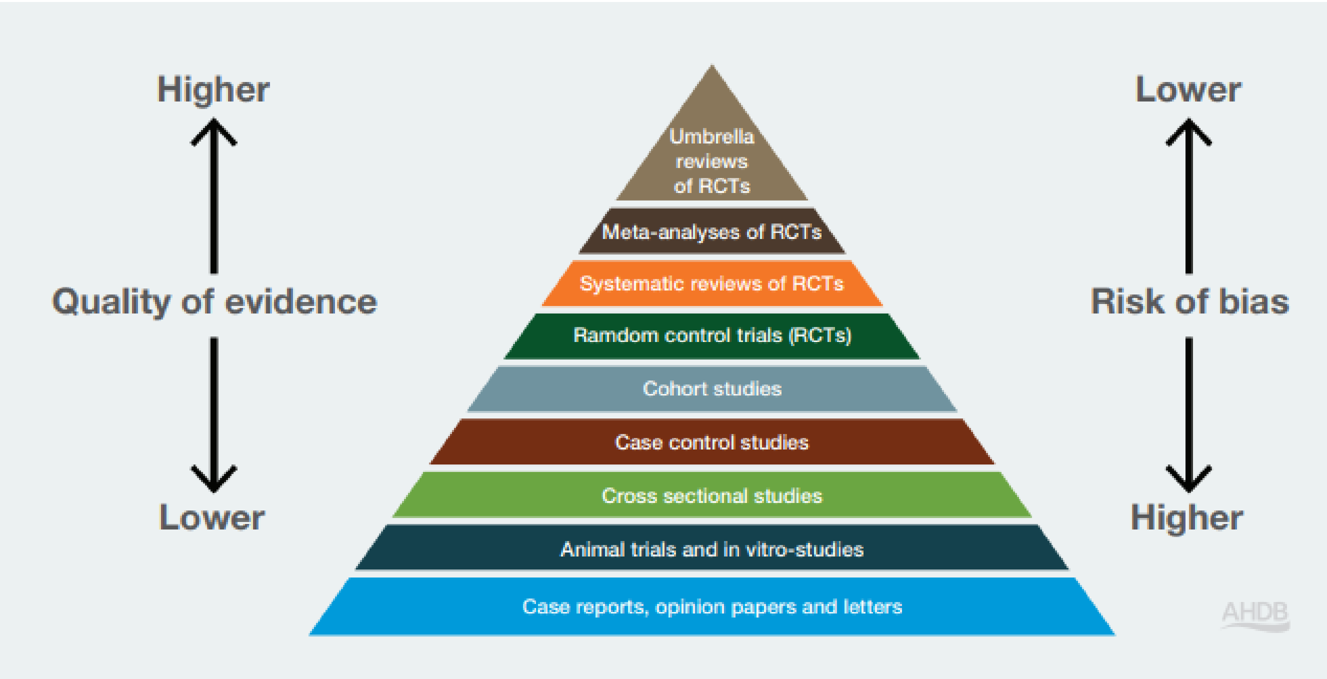
Interestingly, data from UK-based national surveys shows that the nutritional quality of the British diet has not improved much over the last 20 years and may potentially be getting worse. Less than 0.1% of the UK population follow the current Eatwell Guide dietary recommendations.[22, 23] The majority of the UK population are consuming excess calories, saturated fat, salt and sugar and too little fruit, vegetables and fibre.[24–26] Modifiable risk factors, such as physical inactivity and alcohol use, alongside these poor dietary habits all increase the risk of developing NCDs.[27] In contrast, evidence suggests that consuming ≥30 g per day of fibre reduces the risk of developing CVD, T2D and colorectal cancer.[28] However, average intake for adults aged 19–64 is below 19.7 g/day.[24] Considering the aforementioned health statistics and their association with poor food choices, sedentary lifestyle and widening health inequalities, there is compelling evidence that the health status of the UK population is declining.

Consumption of red meat as part of a healthy, balanced and varied diet can play an important role in UK health. Red meat can help meet the nutrient requirements of the most vulnerable population groups, including women of reproductive age, pregnant and lactating women, growth and development in young and adolescent children, as well as older adults. Research provides clear evidence that iron, vitamin B12 and zinc deficiency become more common when less than 30% of calories come from animal-source foods, including meat, eggs, fish and seafood and dairy products.[29] The implication of deficiency in the micronutrients supplied by red meat are covered in more detail on page 60. However, health recommendations advise that high consumers reduce their red and processed meat consumption due to the increased risk of colorectal cancer.[30–32] Some research also suggests a possible link between red meat consumption and increased risk of CVD and T2D. With the potential health and nutritional benefits of red meat, and association between red meat consumption and increased cancer and cardiovascular disease risk, it is important this report identifies the strengths and weaknesses of the research and critically reviews the role red meat may play in the development of chronic diseases.

Critical review of the evidence used in nutrition and health research

The quality of nutrition and health-based research is dependent on the quality and strength of the evidence provided, as highlighted in the hierarchy of evidence pyramid (Figure 1). The weakest research evidence is from studies with risk of bias, denoted at the bottom of the pyramid, and the strongest research evidence comes from studies where the risk of bias is reduced, signified at the top of the pyramid. To help interpretation of the findings presented in this section of the report, definitions of the research terminology are provided in Table 1, while a description of the hierarchy of different research methods and strength of evidence is presented in Table 2.

Figure 1. Hierarchy of scientific evidence pyramid



Source: AHDB

Table 1. Commonly used evidence-based scientific research terminology and tools

Research terminology	Definition
Absolute risk	The likelihood of an event occurring under specific circumstances.[33]
AMSTAR (A MeaSurement Tool to Assess systematic Reviews)	A critical appraisal tool for systematic reviews, designed to help researchers carry out rapid and reproducible assessments of the quality of conduct (as in the methodological quality).[34,35]
Bias	Bias refers to a type of systematic error that can cause an over- or underestimation of the association between exposure and outcome.[36] The study design, including participant selection and conduct, may result in misleading or biased results, which can compromise reliability.[37,38] To minimise bias and improve reporting and transparency, specific guidelines for systematic reviews and meta-analyses are in place.[36]
Causality	The relationship between cause and effect.[38]
Causation	When one thing (a cause) causes another thing to happen (an effect).[39]
Confounding factors	Factors that distort an association because they are associated with an exposure as well as a disease outcome.[36] It is essential to adjust for confounding factors to try to minimise the distortion of results as they can explain part or all the observed association between an exposure and a disease.[40]
Confidence interval (CI)	There is always some uncertainty in research. The confidence interval provides a way to express certainty about the results of a study. It gives the range of results that is likely to include the 'true' result.[38]
Correlation (Association)	When two or more things appear to be related. It can also be described as an 'association'. A correlation or an association does not mean causation.[39]
Dose-response	A term that describes the degree to which an association or effect changes as the level of exposure changes, such as from the intake of a food or drug.[40]
Food frequency questionnaire (FFQ)	Food frequency questionnaires (FFQs) measure a person's average dietary intake over time and are among the best methods for this purpose. However, accurately estimating typical intakes, such as portion sizes and preparation methods, can be challenging. FFQs rely on self-reported data, which can lead to recall bias, as participants may forget or inaccurately report their intake. Additionally, FFQs do not account for lifetime behaviour changes, like a meat eater becoming a vegetarian, which can lead to misclassification and potential bias.[36]
GRADE system	A widely used global standard used to interpret evidence-based research. Established to help address inconsistencies within guidelines to ensure the quality and strength of the evidence is sufficient.[41,42,43]

Hazard ratio (HR)	Broadly equivalent to relative risk (RR), a hazard ratio (HR) analysis is used when the risk is not constant over time. Using information collected at different time points, HR describes survival over time. If HR is 0.5, then the RR of dying in one group is half the risk of dying in the other group. HRs consider more data than RRs and are useful when measuring chronic conditions or long-term outcomes.[44]
Heterogeneity	A measure of the difference between the results of different studies that address a similar question. In a meta-analysis, the degree of heterogeneity may be statistically calculated using the I2 test,[40] where high heterogeneity indicates large differences between studies that should be more closely aligned due to the research question asked. Heterogeneity can make the pooling of data in meta-analysis unreliable or inappropriate.[44]
Hierarchy	A group that is organised and divided into different levels according to their importance or status.[38]
Intervention	The procedures undertaken to manipulate the test subjects and the environment for the purpose of the experiment.[36]
In vitro	Testing of processes that occur outside the body, such as in a laboratory apparatus (in test tubes).[40]
In vivo	Describing biological processes as they are observed to occur within a living cell or organism (in animals).[40]
Longitudinal	A research study carried out over a long time, where data is collected at more than one time point during the study.[38]
Modelling	A type of statistical analysis that identifies all of the important factors that can help to decide on the best approach to take. It uses data collected from previous studies to answer a research question.[38]
NutriGrade system	A scoring system to assess the meta-evidence of an association or effect between different nutrition factors and outcomes (e.g. hard clinical endpoints or surrogate markers).[45]
Observational data	Data is collected through observation of research participants, where observational research attempts to understand the cause and effect of relationships. Researchers do not influence or intervene but rather observe to see the results.[38]
Relative risk (RR)	The likelihood of an event occurring in a group of people compared with another group with different behaviours, physical conditions or environments. Absolute risk numbers are needed to understand the RR.[33] It represents the number of times more likely (RR>1) or less likely (RR<1) that an event will occur in one group compared with another. Reported as follows (RR) 1.34, (95% CI (confidence interval): 1.04–1.13), where RR is the % risk (34%) and 95% CI represents the level of confidence in the findings (4–13%). A RR <2.0 is considered to have too much risk of confounding, so a small RR may be too crude to distinguish between bias, confounding and causation.[46]
Rigorous	Being thorough and precise. This term is used to describe the quality of the methods used within the study. Rigorous research methods comply with a specific set of quality standards.[38]
Risk	The probability that an event will occur.[36]

Validity	The soundness or rigour of a study. A study is internally valid if the way it is designed and carried out means that the results are unbiased and give an accurate estimate of the effect that is being measured. A study is externally valid if its results apply to people studied in clinical practice.[44]

Table 2. Hierarchy of research methodology: Definitions and classification by type

Research method	Definition	Type of research
Umbrella analysis	A review of systematic reviews and meta-analyses, providing A review of systematic reviews and meta-analyses, providing an overview of the findings. It is one of the highest levels of research evidence,[47] an overview of the findings. It is one of the highest levels of research evidence.[47]	Tertiary: research overview
Meta-analysis	A meta-analysis is the statistical combination of results from several independent trials to produce an overall result. A systematic review will often include a meta-analysis.[37]	Secondary: research overview
Systematic reviews	A systematic review combines the results of several original studies which have been systematically searched out and judged on pre-defined inclusion criteria, and a synthesis of their results is produced.[37]	Secondary: research overview
Randomised-controlled trials (RCTs)	Trial participants are randomly assigned to either a control group or a treatment group to receive a specific intervention. The aim is to control all other factors that may influence the effect of the intervention.[37]	Primary: experimental research
Prospective cohort studies	Two or more groups of people who have a different exposure to a particular agent (such as the type of diet or a nutrient) are selected and then followed up to see what differences there are between the groups for specific outcomes.[37]	Primary: observational research
Case-control studies	People with a particular condition (cases) are matched with people without the condition (controls) and differences are then examined in a retrospective analysis.[37]	Primary: observational research
Cross-sectional studies	An examination of a sample of the population of interest at one point in time. Surveys often use a questionnaire or interview design.[37]	Primary: observational research
Animal trials and in-vitro studies	Animal and cell (in vitro) studies can help to understand potential human reactions, but the findings cannot be applied directly to humans, and cells in a lab behave differently than in the body. They complement observational and experimental studies by showing whether a specific mechanism can explain the result.[36]	Primary: mechanistic research
Anecdotes, case reports and studies, opinion papers, editorials	Anecdotes, case reports (usually on one patient) and case studies (on several patients) provide a detailed report of individual patient(s) with a specific outcome or exposure. They can provide early indications of health problems and may be used to generate hypotheses about possible causes. However, being limited by the number of people involved, they cannot be generalised to the wider population. The experience or opinion of one person does not provide an objective picture. For this reason, anecdotes and case studies are considered low-quality evidence.[36]	Primary: descriptive and expert commentary
Hierarchy of evidence baseline		

Source: Primarily adapted from Hickson et al., (2024)[37] with additional references as highlighted

The different experimental research methods that are often used to determine the impacts of red meat on health are briefly discussed below.

Primary research

Primary research methods can be divided into observational and experimental approaches.

Observational research

This includes studies such as cross-sectional, case-control and prospective cohort designs, as detailed in Table 2. In prospective cohort studies, participants are followed over time to investigate the relationships between exposures (e.g. red meat consumption) and outcomes (e.g. health issues, disease development or mortality). These studies identify correlations or generate hypotheses for further testing, offering insights into long-term effects of diet and lifestyle on health.[48] However, they are prone to biases and confounding factors, such as self-reported data and the difficulty of controlling all variables, which limits their ability to establish causation.[48] While observational studies have informed recommendations to limit red and processed meat consumption,[30–32,49] they cannot definitively prove cause and effect relationships and more research is required.[50]

Experimental research

This involves methods like randomised controlled trials (RCTs), where participants are randomly assigned to treatment or control groups and outcomes are measured to assess the impact of an intervention. RCTs are considered the gold standard for establishing causality.[50] However, they also have limitations, including challenges in studying the effects of entire diets on chronic diseases, issues with compliance, reliance on disease markers rather than actual outcomes and the need for larger longer-duration studies to produce more reliable results.

Secondary research

Secondary research includes systematic reviews and meta-analyses which combine and analyse multiple studies (e.g. cohort studies or RCTs) to assess the strength and quality of evidence. Systematic reviews pool and critically appraise evidence, while meta-analyses apply statistical techniques to generate more precise estimates. Both methods aim to reduce bias, though the quality of the included studies affects the reliability of the results.[50] The assessment methods used ensures inclusion of appropriately designed studies, evaluates methodological quality and applies assessment frameworks, such as GRADE (Grading of Recommendations Assessment, Development and Evaluation) (Table 1) to determine the certainty of evidence.[37] Systematic reviews and meta-analyses of RCTs typically provide stronger evidence than observational studies.

Relative risks (RR) and hazard ratios (HR) are commonly used to summarise and compare risks across studies (Table 1). However, they can be misleading if assumptions are violated,[36] so careful adjustment for confounders and clear communication are essential for accurate interpretation, as explained in more detail (Table 1, page 109).

Tertiary research

Tertiary research

This includes umbrella reviews which synthesise findings from multiple systematic reviews and meta-analyses, providing the highest level of evidence. Evidence-based nutrition prioritises the use of the highest-quality evidence, particularly from systematic reviews, meta-analyses and umbrella reviews that adhere to rigorous guidelines and quality standards, to guide recommendations and decisions. The next section discusses the role of red meat in chronic disease, drawing on evidence from across the research hierarchy.

Red meat and non-communicable diseases

Non-communicable diseases (NCDs) such as cardiovascular disease (CVD), diabetes, chronic respiratory diseases and cancer cannot be transmitted between people.[51] They are linked to factors like weight gain, obesity and poor dietary habits, including not meeting dietary recommendations.[52] NCDs account for 74% of global deaths each year,[27] with 21% of premature NCD deaths occurring in the UK (ages 30–70). The risk of dying from CVD, cancer or chronic disease is 10%.[53] A healthy, balanced diet is crucial for reducing NCD risk. This section reviews the evidence on red meat consumption and its association with NCDs, such as colorectal cancer, CVD and type 2 diabetes (T2D), in the context of UK dietary guidelines and health recommendations.

Red meat and cancer risk

In 1998, the UK Committee on Medical Aspects of Food and Nutrition Policy (COMA) recommended reducing red and processed meat intake to lower colorectal cancer risk. They advised that adults consuming more than 90 g/day cooked weight should consider reducing their intake.[49]

In 2007, the World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR) reinforced this recommendation,[30] based on observational studies linking red and processed meat consumption to increased colorectal cancer risk.

A summary of health recommendations from various health organisations, including the UK's Scientific Advisory Committee on Nutrition (SACN) between 2007–2017, is provided below. The research findings, including colorectal cancer rates, are discussed to highlight the associated risks of red and processed meat consumption.

Health-based colorectal cancer prevention recommendations

- WCRF recommends limiting red meat to three portions per week (~300–500 g or 12–18 oz cooked weight) and consuming little to no processed meat.[30] They emphasise that meat should not be completely avoided as it provides essential nutrients like protein, iron, zinc and vitamin B1254

- SACN recommends a maximum of 500 g/week or 70 g/day (cooked weight) of red and processed meat. In the UK, those consuming more than 90 g per day are advised to reduce intake to 70 g or less.[31] Unlike WCRF, SACN provides a combined limit for both red and processed meat

- The World Health Organization (WHO) recommends moderating processed meat consumption to reduce colorectal cancer risk, based on the International Agency for Research on Cancer (IARC) evaluation[32]

The research behind the current health recommendations

Numerous studies, mainly cross-sectional observational research, have examined the link between red meat consumption and cancer. Key reports include the WCRF/AICR Continuous Update (CUP) series which began in 1997 and is updated every 10 years.[55] Table 3 summarises findings from meta-analyses of observational cohort studies on colorectal cancer risk and meat consumption, including reports from WCRF/AICR (2007 and 2017), the UK Scientific Advisory Committee on Nutrition (SACN) and WHO's International Agency for Research on Cancer (IARC).

Table 3: Red and processed meat intake and risk of colorectal cancer from meta-analyses of observational cohort studies– 10 years of data

Type of meat		WCRF/AICR 2007[1]	SACN 2010[2]	IARC (WHO) 2015[3]	WCRF/AICR 2017[4]
Red meat	RR for red meat	1.29 per 100 g serving	1.17 (based on the median RR) comparing high vs. low intake	1.17 per 100 g serving	1.12 per 100 g serving
	Statistic:	(RR 1.29 (95% CI, 1.04–1.6))	-	(RR 1.17 (95% CI, 1.05–1.31))	(RR 1.12 (95% CI, 1.00–1.25))
	Association ranking	Convincing	Probable	Limited	Probable
Processed meat	RR for processed meat	1.21 per 50 g serving	1.16 (based on the median RR) comparing high vs. low intake	1.18 per 50 g serving	1.16 per 50 g serving
	Statistic:	(RR 1.21 (95% CI, 1.04–1.42))	-	(RR 1.18 (95% CI, 1.10–1.28))	(RR 1.16 (95% CI, 1.08–1.26))
	Association ranking	Convincing	Probable	Sufficient	Convincing

Key: RR = relative risk; CI = confidence interval; MA = meta-analyses

Association ranking based on the evidence base for the risk of colorectal cancer:

Convincing evidence is strong enough to support a judgement of a convincing causal relationship, which justifies making recommendations to reduce the risk of cancer. The evidence is robust enough to be unlikely to be modified in the foreseeable future as new evidence accumulates.[7]

Probable evidence is strong enough to support a judgement of a probable causal relationship, which generally justifies goals and recommendations designed to reduce the risk of cancer.[7]

Limited evidence means that a positive association has been observed between exposure to the agent and cancer but that other explanations for the observations (technically termed, chance, bias or confounding) could not be ruled out.[32]

Sufficient evidence is where there is convincing evidence that the agent, such as a food, causes cancer, based on sufficient evidence from epidemiological studies that eating processed meat causes colorectal cancer.[32]

SACN 2010

The 2007 WCRF/AICR CUP report initially provided “convincing” evidence linking red and processed meat to colorectal cancer.[30] In response, SACN conducted a review of the evidence in their Iron and Health report.[31]

While examining meta-analysis data from observational research studies, SACN questioned the quality of the available data, noting inconsistencies in how red and processed meat was categorised and quantified. They concluded that it was “not possible to determine a clear dose-response relationship, or a threshold level of intake linked to increased colorectal cancer risk”.[31]

SACN also referenced a pooled analysis[57] of data from two UK studies (n=61,566) comparing cancer incidence in vegetarians versus meat eaters.[58,59] After 12 years of follow-up, no significant difference in colorectal cancer risk was found between the two groups (RR 1.12 (95% CI, 0.87–1.44).[59] However, SACN acknowledged that the analysis did not fully capture meat consumption patterns and that intake levels were much lower than average NDNS intakes.[60]

Based on the available evidence, SACN concluded that it was "probable" that high red and processed meat intake increased colorectal cancer risk but could not definitively confirm it. SACN then sought to establish appropriate dietary recommendations for red and processed meat intake. SACN conducted modelling to assess the impact of varying meat consumption (from 180 g to 0 g per day, in 10 g increments) on UK population micronutrient status, including iron and zinc.[31] Considering the implications of their findings, they recommended a maximum of 500 g/week or 70 g/day (cooked weight) of red *and* processed meat, advising those who consume greater than 90 g/day to reduce their intake to less than 70 g/day.

IARC 2015

In 2015, the WHO's International Agency for Research on Cancer (IARC) classified red meat as probably carcinogenic to humans, based on "limited" evidence linking consumption (>100 g per day) to colorectal cancer and strong mechanistic evidence supporting a carcinogenic effect. However, IARC acknowledged that other factors, such as chance, bias or confounding, could not be ruled out.[32]

IARC classified processed meat as carcinogenic to humans based on "sufficient" evidence of a direct link to colorectal cancer from consuming >50 g/day. Their public statement[61] concluded that "each 50 gram portion of processed meat increases colorectal cancer risk by 18%", based on evidence from 10 studies. This reinforced the 2002 WHO recommendation to moderate processed meat consumption.[32] However, media coverage of the 18% increased risk led to confusion about the actual risk of colorectal cancer from processed meat consumption.

WCRF/AICR 2017

In 2017, WCRF/AICR conducted a meta-analysis of observational cohort studies and found that consuming 100 g of red meat per day increased colorectal cancer risk by 12%, while consuming 50 g of processed meat per day raised the risk to 16%.[7] Based on these findings, red meat was considered a "probable" cause of colorectal cancer, and processed meat classified a "convincing" cause (Table 1). Notably, these findings showed a weaker association than previous reviews, with the relative risk for red meat dropping from 29% to 12% and for processed meat from 21% to 16%[30] (Table 1).

Due to the strength of the evidence linking red meat to colorectal cancer, WCRF/AICR downgraded their classification from "convincing" in 2007 to "probable" in 2017, despite including the same number of studies and 2,000 additional colorectal cancer cases.[7] This change occurred because the 2018 review revealed a significant dose-response relationship for colon cancer, but not for colorectal or rectal cancers. Three pooled analyses showed no significant association, though were consistent in the direction.[7,62]

In their 2017 report, WCRF/AICR concluded that being overweight or obese, alcohol consumption and processed meat consumption all had "convincing" evidence of increased colorectal cancer risk.[7] In contrast, consumption of wholegrains, fibre and dairy products "probably" reduced the risk of colorectal cancer. Moderate to vigorous physical activity was also deemed "convincing" evidence of protection. These findings reiterate the importance of a healthy, balanced diet (as per the Eatwell Guide),[23] portion control, monitoring alcohol intake and maintaining an active lifestyle to prevent obesity and reduce cancer risk.

Colorectal cancer incidence rates within the UK

Colorectal cancer is the third most common cancer in the UK, after lung, prostate and breast cancer, accounting for 11% (n=26,593 cases) in men and 10.7% (n=22,836 cases) in women, with a total 49,429 cases, based on 2022 data.[63] In Europe, including the UK data, there were 289,251 cases of colorectal cancer in men and 249,333 cases in women.[63]

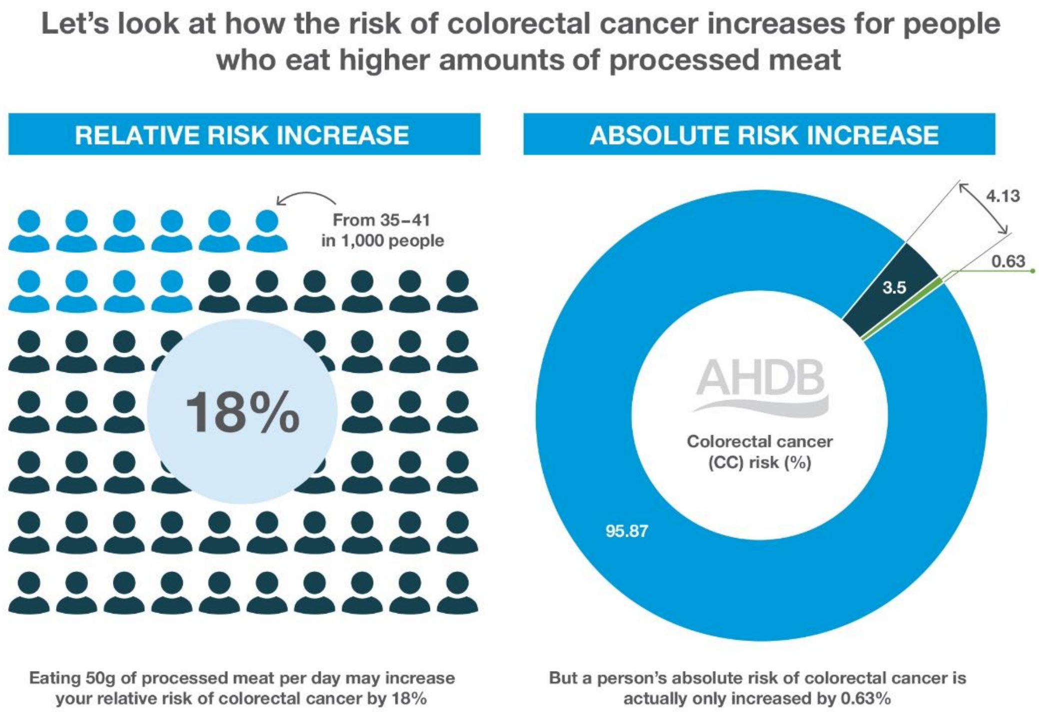
Colorectal cancer risk assessment based on the IARC (2015) findings

To assess the cancer risk from consuming >50 g of processed meat per day, we need to consider both the absolute risk (lifetime risk of developing colorectal cancer) and relative risk (increased risk associated with red meat consumption) (see Figure 2). In the UK, the absolute risk of colorectal cancer is 3.5%.[63] The relative risk for consuming >50 g of processed meat per day is an 18% increase. Combining these values, we can calculate the actual increased risk as follows.

Lifetime risk of colorectal cancer from consuming >50 g of processed meat per day:

- 18% of 3.5% (RR) = 0.63%, the additional risk of consuming >50 g of processed meat per day
- Adding absolute risk (3.5%) + the increased risk (0.63%) gives a lifetime risk of 4.13%, or one additional case of colorectal cancer for every 200 individuals

Figure 2. UK risk of colorectal cancer in those consuming higher than average amounts of processed meat



Source: adapted from **https://www.meat.nl/publicaties/GFJAmeatfactsguide.pdf**

Colorectal cancer risk and red meat consumption rates

While the highest average intake of processed meat in UK adults (40.2 g/day for ages 19–39) and red meat (42.2 g/day for ages 40–64) is below the risk thresholds of 50 g and 100 g per day, some individuals exceed these amounts. For example, some adults aged 40–64 consume up to 213.48 g of processed meat and 249.91 g of red meat per day,[64] which may increase their colorectal cancer risk (Table 5).

Table 5. Average red vs. processed meat intakes and range (g/day) in adult consumers (19+ years)

Intake g/day	Age (years)			
	19+ (n=1844)	19–39 (n= 572)	40–64 (n= 820)	65+ (n=452)
Red meat	40.24 g	40.42 g	42.20 g	36.82 g
Range	0.01–249.91 g	0.07–232.81 g	0.01–249.91 g	0.03–142.85 g
Processed meat	35.97 g	40.21 g	36.26 g	29.98 g
Range	0.04–213.48 g	0.04–164.15 g	0.06–213.48 g	0.06–133.42 g

Source: BNF, 2023a[64]

Efforts to reduce colorectal cancer risk should focus on individuals consuming over 100 g of red meat and 50 g of processed meat per day, especially adult males aged 19–64, who have higher intakes according to the 2017–19 NDNS report.[24] The 2024 Food Standards Scotland (FSS) report also highlights the need to target high meat consumers, particularly young men,[65] as 86% of Scottish adults consume meat, averaging 94 g per day, with high-end consumers (aged 25–34) eating 117 g daily, mainly in meals like spaghetti Bolognese, lasagne, chilli con carne or ham sandwiches.

Modelling reduced red and red processed meat intake for high-end consumers to no more than 70 g per day, aligning with the current UK health recommendations.[30,31] This identified a 16% decrease in total meat intake, affecting 28% of Scottish adults.[65] The estimated long-term health benefits included small reductions in BMI, CVD cases and ~10,000 fewer type 2 diabetes (T2D) cases over 10 years achieved by replacing meat with pulses, vegetables, eggs or fish. However, the modelling was hypothetical, and food choices will differ in real-life scenarios; substitutions could involve less healthy options. Reducing meat intake to ≤70 g per day helped prevent micronutrient insufficiencies but reductions below 60 g/day risked lowering levels of iron, selenium, zinc and vitamin B12, in an already nutritionally vulnerable population.[65]

This highlights the need to align dietary intakes with the Eatwell Guide, as the public is already falling short of these recommendations.[22,24] FSS warns that prioritising red and processed meat reductions to meet Climate Change Committee (CCC) environmental goals[66] without considering micronutrient needs could harm vulnerable groups with already inadequate or increased nutrient requirements.[65] The focus should be on encouraging adherence to current guidelines, particularly by helping high-end consumers reduce their intake to <70 g/day of red and processed meat.

Confounding factors in observational research

Confounding is a key issue in observational research and cannot be overlooked. For example, individuals who consume large amounts of processed meat often eat significantly less poultry, fish and vegetables, and a diet high in haem iron typically reflects high meat and fish consumption.[7] These factors may influence the observed effects of red and processed meat intake. WCRF/AICR note that while some studies adjust for dietary fibre, few account for fruit and vegetable intake, and further analysis of confounding factors was not performed in their report.[7] Similarly, IARC could not rule out bias, chance or confounding as plausible reasons behind the positive association found.[32]

Possible mechanisms behind increased risk of colorectal cancer

When examining the link between red meat consumption and colorectal cancer risk, it is important to consider potential mechanisms, such as the production of harmful compounds from high-temperature cooking, the high haem iron content in red meat and the role of high-fat diets and obesity in carcinogenesis. While these mechanisms are briefly discussed, the focus of this report is on evidence from large systematic reviews and meta-analyses.

Cancer-causing compounds

Cooking meat or fish at high temperatures (up to 400°C), through methods like grilling, frying, barbecuing and roasting, can produce compounds such as heterocyclic aromatic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs) which are linked to increased cancer risk, as indicated by IARC[56] and WCRF/AICR.[7] HCAs form when amino acids in muscle meat react with creatine at high temperatures,[30] while PAHs arise from incomplete combustion, especially in barbecued meats and tobacco smoke.[67] However, evidence connecting HCAs to cancer risk is inconclusive[68] and while PAHs are linked to overcooked meat, the epidemiological and experimental evidence for this remains insufficient.[67] Interestingly, similar compounds form when cooking fish and chicken at high temperatures, but these foods are not associated with increased cancer risk.[62,68] Research suggests roasting is less harmful than barbecuing or frying as it produces fewer of these compounds.[70]

The International Agency for Research on Cancer (IARC 2018)[56] acknowledges a link between meat consumption and cancer risk but has not definitively concluded cooking methods influence this risk. They note that the role of compounds formed during high-temperature cooking is still unclear and could not attribute the risk to a specific meat component. Moreover, they acknowledge that meat is not the only source of cancer-causing compounds.[32,56] To reduce exposure, consumers can be guided towards alternative cooking methods, such as steaming, poaching or slow cooking, and encouraged to adopt healthier recipes, with smaller meat portions combined with more plant-based ingredients, which may help mitigate compound formation and provide additional complementary nutrients.

Haem iron and cancer risk

Haem iron, found in higher levels in red than white meat, may promote the formation of N-nitroso compounds (NOCs) in the gut,[71–73] which are linked to increased colorectal cancer risk. This may partly explain the stronger association between red meat consumption and colorectal cancer risk, though it does not clarify why white meat and fish might have a protective effect.[71–73]

N-nitroso compounds are formed when nitrates and nitrites in processed meats react with other organic compounds, such as secondary amines and N-alkylamides.[67] They can also be synthesised in the gut, specifically the colon, where haem iron may catalyse their formation.[71–73] NOCs are alkylating agents that can bind to DNA, creating cancer-causing DNA adducts. While red meat consumption is linked to elevated faecal NOC levels, it remains uncertain whether NOCs from red meat specifically contribute to cancer risk.[69]

Consuming high red meat (300 g/day) with fibre-rich products such as butyrylated high-amylose may help prevent DNA adduct formation in humans.[74] A daily intake of ≥30 g of fibre is associated with a lower colorectal cancer risk,[31] but current fibre intakes are around one-third below this recommendation.[24] While more research is needed, WCRF/AICR (2018)[7] concluded that evidence linking haem iron consumption to colorectal cancer risk is limited.

Fat

Epidemiological and animal-based research studies have suggested a link between high dietary fat intake and colorectal cancer risk, but findings are mixed. Some animal studies show high-fat diets may increase tumours, while others find no effect. However, much of this research is outdated,[67] and animal findings may not apply to humans.

More recent evidence offers little support for the role of fat in red meat fat on cancer risk.[71] The WCRF/AICR report also finds limited evidence that animal fat directly contributes to colorectal cancer.[7] However, saturated fat can increase overall energy intake, contributing to individuals becoming overweight and obese, so consumption of leaner cuts of red meat and healthier cooking methods are advised.

Obesity as a result of high fat intake may directly contribute to colorectal cancer risk. WCRF (2018) concluded that adult body fatness increases the risk of colorectal cancer,[7] a concern given that one in four UK adults are obese and nearly two in five are overweight.[2] This highlights the importance of healthier eating habits, such as following the Eatwell Guide[23] to reduce the risk of developing different NCDs.

Summary of research findings on red meat and colorectal cancer risk

Health guidelines recommend limiting red and processed meat consumption due to their association with colorectal cancer risk. Specifically, high consumers (>90 g/day) are advised to reduce intake to 70 g/day (500 g/week).[30, 31, 23] Early observational research suggested there was "convincing" evidence for a strong link between red meat and colorectal cancer risk,[30] but evidence has since been downgraded to a "probable" cause.[7] In contrast, WCRF/AICR maintains that processed meat is a "convincing" cause of colorectal cancer (50 g/day).[7,30]

SACN also classified the risks of both red and processed meat as "probable" for colorectal cancer risk,[31] while IARC deemed red meat as "probably" carcinogenic and processed meat as carcinogenic.[32]

Despite evidence suggesting mechanisms linking red and processed meat consumption to increased colorectal cancer risk, the data remains inconclusive. Observational studies are prone to bias and confounding, as acknowledged by WCRF and IARC, such as the tendency for high meat consumers to eat fewer fruit and vegetables. This highlights the need for more rigorous research with better controls for bias and confounding to understand the mechanisms behind the higher risk of colorectal cancer in processed meat consumers. Scientists are also calling for more stringent research methods to avoid overestimating risk.[76]

The average intake for red and processed meat in the UK is below the recommended limit of 70 g per day (~500 g per week), with the highest average intake being 42 g and 40 g per day, respectively.[64] However, some individuals consume much higher amounts, with daily intakes reaching 250 g of red meat and 213 g of processed meat.[64] Reducing intake to 70 g per day could decrease total meat consumption by 16% and improve health outcomes, though further reductions beyond this recommendation could adversely impact population micronutrient intakes.[65]

Being overweight or obese is a convincing risk factor for colorectal cancer, while consumption of dairy, wholegrains and fibre-rich foods "probably" decrease the risk, while moderate to vigorous physical activity is deemed to have convincing evidence of a decreased risk. Promoting a healthier diet and lifestyle in line with the UK Eatwell Guide[24] is crucial, especially given the role of obesity as the second leading cause of cancer[3,75] and the rising rates of overweight and obesity.[2]

The revised Global Cancer Update programme aims to provide more frequent updates[75] and may clarify the role of red and processed meat consumption in colorectal cancer risk based on new evidence. Until then, cancer prevention recommendations from the 2018 WCRF/AICR report remain unchanged, including the advice to limit red meat (beef, lamb and pork) to moderate amounts and to consume little to no processed meat.[7]

Red meat and cardiovascular disease

Cardiovascular disease (CVD)

Cardiovascular disease (CVD), including coronary heart disease (CHD), atrial fibrillation, heart failure (HF), stroke and vascular dementia, causes around 175,000 deaths annually in the UK,[8] accounting for 27% of all deaths. CHD, the most common CVD, results from artery blockages due to a build-up of fatty plaques (atherosclerosis) and is the leading cause of death worldwide, contributing to 68,000 UK deaths each year, with one in eight men and one in fourteen women dying from the disease.[8]

Diet significantly impacts CVD risk. High saturated fat intake is linked to CHD, by promoting atherosclerosis, leading to thickening or hardening of arteries causing heart attacks, strokes and other CVDs.[77,78] In contrast, unsaturated fats can help reduce cholesterol[80] and improve heart health.[79] Being overweight or obese, poor dietary choices and high salt intake leading to high blood pressure further increase CVD risk.[4] With 30% of UK adults having high blood pressure,[8] it is recommended to limit salt intake to less than 6 g/day.[81] A healthy, balanced diet, reducing saturated fat, salt and sugar, along with regular physical activity can help reduce CVD risk.[82]

The saturated fat and salt content of foods varies based on preparation, processing and cooking methods. Processed foods, home-prepared meals and food from restaurants differ in composition affecting CVD risk. Processed meats typically contain higher levels of saturated fat and salt than lean cuts of red meat (see page 58, Table 14).

Relationship between red meat and CVD risk

Observational studies and randomised controlled trials (RCTs) have explored the link between red and processed meat consumption and cardiovascular disease (CVD) risk and mortality. Accurate food intake recording and controlling for confounding factors are essential.

The research is presented chronologically in a summary table with relevant relative risk (RR) or hazard ratio (HR) findings (see Table 6).

Observational research: Meta-analyses of prospective cohort studies linking red meat and cardiovascular disease

Consumption of red and processed meat and its relationship to cardiovascular disease and related deaths

Meta-analyses on red and processed meat consumption and cardiovascular disease (CVD) risk have shown mixed results.[83,89] During a 9.5-year follow-up of Prospective Urban Rural Epidemiology (PURE) study participants, there were 7,789 deaths and 6,976 cardiovascular disease events, but there was no significant association between higher red meat consumption (≥250 g/wk vs <50 g/wk) and total mortality (HR:0.93: 95% CI:0.85–1.02) or major cardiovascular disease events (HR:1.01: 95% CI:0.92–1.11).[89] However, processed meat intake (≥150 g/wk vs 0 g/wk) was linked to higher total mortality (HR:1.51: 95% CI:1.08–2.10) and major cardiovascular events (HR:1.46: 95% CI:1.08–1.98).[89] A second meta-analysis of 13 cohort studies totalling 1.67 million participants found that processed meat was associated with an 18% (RR: 1.18) higher risk of CVD mortality, while red meat showed a 16% (RR:1.16) increase.[83] Dose-response analysis indicated that each 50 g/day increase in processed meat raised CVD mortality by 24%, compared with 15% for red meat consumed at 100 g/day.[83] While both red and processed meat are linked to higher CVD events and mortality risk, the authors highlight that the associations, especially with red meat, are weak and subject to variability due to study methodologies and confounding factors.

Consumption of red and processed meat and its relationship to high blood pressure or stroke

Studies examining the effects of red and processed meat on high blood pressure and stroke risk consistently show an increased risk, though results vary across studies.[84–86] A systematic review and meta-analysis of 28 cohort studies comparing lowest and highest intake of 12 major food groups found that consuming more than 100 g/day of red meat was linked to a 14% higher risk of hypertension (RR: 1.14), while 50 g/day of processed meat increased the risk by 12% (RR: 1.12).[84] Dose-response analysis from the same study indicated that increasing red meat intake to an extreme 200 g/day raised the hypertension risk to 40%, while processed meat intakes of 30 g/day raised the risk to 7%.[84] These findings highlight that both red and processed meat consumption are associated with an increased risk of hypertension, with processed meat showing a slightly lower but still significant impact.

In terms of stroke risk, Kim et al. (2017)[85] found that red meat consumption was linked to an 11% increased risk of stroke (RR: 1.11), while processed meat showed a stronger association, with a 17% higher risk (RR: 1.17). Similarly, Bechtold et al. (2019)[86] found that processed meat consumption was associated with a 16% higher risk of stroke, while red meat showed a 12% increase. Both studies suggest that high consumption of red and processed meat significantly raises the risk of stroke, with processed meat showing a stronger association. Overall, these studies support the conclusion that higher intake of both red and processed meats is linked to elevated risks of hypertension and stroke, with processed meat posing a greater risk for both conditions.

Consumption of red and processed meat and coronary heart disease or heart failure

The relationship between 12 major food groups (whole and refined grains, vegetables, legumes, eggs, dairy, fish, red meat, processed meat and sugar-sweetened beverages) on the risk of coronary heart disease and HF was investigated by Bechthold et al. (2019).[86] Comparing the highest versus lowest intakes of red meat, the study found that higher consumption of red meat was positively associated with both CHD (RR 1.16) and HF (RR 1.12). Specifically, each additional 100 g/day increase in red meat consumption increased CHD risk by 15% and HF risk by 8%. Processed meat intake also showed a positive association, with the highest intakes linked to a 15% increased risk with CHD and a 27% higher risk of HF. The dose-response analysis revealed that an additional 50 g/day of processed meat raised CHD risk by 27% and HF risk by 12%. Notably, the risk of HF increased significantly by 25% when processed meat consumption reached 70 g a day. These findings support current dietary guidelines that emphasise the consumption of vegetables, fruits, whole grains, legumes, nuts and fish, while limiting red and processed meat intake to reduce the risk of CHD and HF.

Table 6. Summary of relative risk and hazard ratio reported in CVD observational research

Research paper	Research type	CVD risk assessment	Increased risk
Abete et al. 2014	Dose response meta-analysis	Red meat and mortality from CVD	RR 1.16 (95% CI: 1.03–1.32)
		Processed meat and mortality from CVD	RR 1.18 (95% CI: 1.05–1.32)
		Red meat and mortality from CVD (100 g/d)	RR 1.15 (95% CI: 1.05–1.26)
		Processed meat and mortality from CVD (50 g/d)	RR 1.24 (95% CI: 1.09–1.40)
Schwingshackl et al. 2017	Dose-response meta-analysis	Red meat and hypertension (100 g/day)	RR 1.14 (95% CI: 1.02–1.28)
		Processed meat and hypertension (50 g/day)	RR 1.12 (95% CI:100–1.26)
Kim et al. 2017	Meta-analysis	Total meat and stroke incidence	RR 1.18 (95% CI: 1.09–1.28
		Red meat and stroke incidence	RR 1.11 (95% CI: 1.03–1.20)
		Processed meat and stroke incidence	RR 1.17 (95% CI: 1.08–1.25)
Bechtold et al. 2019	Dose response meta-analysis	Red meat and CHD events	RR 1.16 (95% CI:1.08–1.24)
		Processed meat and CHD events	RR 1.15 (95% CI: 0.99–1.33)
		Red meat and stroke incidence	RR 1.12 (95% CI: 1.06–1.17)
		Processed meat and stroke incidence	RR 1.16 (95% CI: 1.07–1.26)
		Red meat and heart failure	RR 1.12 (95% CI: 1.04–1.21)
		Processed meat and heart failure	RR 1.27 (95% CI: 1.14–1.41)
		Red meat and CHD events (100 g/day)	RR 1.15 (95% CI: 1.08–1.23)

		Processed meat and CHD events (50 g/day)	RR 1.27 (95% CI: 1.09–1.49)
		Red meat and stroke incidence (100 g/day)	RR 1.12 (95% CI: 1.06–1.17)
		Processed meat and stroke incidence (70 g/day)	RR: 1.17: (95% CI 1.02–1.34),
		Red meat and heart failure (100 g/day)	RR 1.08 (95% CI: 1.02–1.14)
		Processed meat and heart failure (50 g/day)	RR 1.12 (95% CI: 1.05–1.19)
Iqbal et al. 2021	Dose-response meta-analysis	Consuming ≥150 g vs. 0 g of processed meat and CVD events	HR 1.46 (95% CI: 1.08–1.98)
		Consuming ≥150 g vs. 0 g of processed meat and CVD mortality	HR 1.51 (95% CI:1.08–2.10)

Key: Relative risk (RR) is the likelihood of an event occurring in a group of people compared with another group.[33] An RR <2.0 is considered to have too much risk of confounding[46]

95% confidence interval (CI) represents the level of confidence in the findings, which lies between the two values

Hazard ratio (HR) is used when measuring chronic conditions or long-term outcomes; it describes survival over time[44]

Umbrella reviews of observational studies

The growing number of systematic reviews and meta-analyses in this field led to the publication of umbrella reviews, to provide a comprehensive overview of the evidence on the relationship between meat intake and various non-communicable diseases (NCDs).

Key umbrella review findings on the relationship between red meat consumption and cardiovascular disease risk

Three umbrella reviews were conducted to assess the relationship between meat consumption (red, processed and poultry) and the risk of cardiovascular diseases (CVD), coronary heart disease (CHD), stroke and other cardiovascular outcomes (Jakobsen et al. 2021; Grosso, et al. 2022; Hill, et al. 2024).[91–93]

The first umbrella review,[91] focusing on three systematic reviews published between 2010 and 2020,[85–87] found moderate evidence linking higher processed meat intake to increased risks of CHD and stroke, while unprocessed red meat and poultry intake was associated with a lower risk of stroke. However, red meat (unprocessed) and processed meat were not clearly associated with overall CVD risk. The evidence for these associations was generally graded as moderate for processed meat and low for other meat types, with many studies exhibiting critical flaws. The review highlighted the need for more rigorous studies comparing different types of meat and non-meat protein sources.

The second umbrella review analysed 59 meta-analyses of cohort studies on meat consumption and various health outcomes, including CHD, CVD and mortality.[92] It found "possible" evidence linking red and total red meat consumption to an increased risk of CHD and stroke, but no "convincing" or "probable" evidence for an association between total red or processed meat with CHD- or CVD-related mortality. "Limited" evidence was found for red meat and CVD mortality, and processed meat consumption for CVD and CHD mortality. However, the authors concluded that the heterogeneity of the results did not allow for clear recommendations on optimal meat consumption levels. The review also noted that while excess meat consumption may be harmful, the evidence does not strongly support causality.

The most recent umbrella review of 29 systematic reviews and meta-analyses evaluated the impact of higher red and processed meat intake on cardiovascular disease (CVD) and type 2 diabetes (T2D).[93] Combining data from

22 observational studies and seven randomised controlled trials (RCTs), the review used the Bradford Hill Causality Criteria to assess causality[94] and the AMSTAR2 tool for quality.[35] The studies considered various definitions of red and processed meat, but inconsistencies in terminology were noted, highlighting the need for clearer definitions in future research. The review found weak associations between meat intake and CVD in observational studies, with RCT results largely non-significant and lacking consistency with observational data. Using causality criteria, the authors concluded that while temporality and plausible mechanisms were identified, the evidence did not support a causal link between red and processed meat intake and CVD risk. The review emphasised the need for more high-quality experimental RCT research, particularly on processed meat, to better understand its health risks.

To summarise the comprehensive umbrella reviews, they all highlight the need for more consistent definitions of meat types in research, improved methodological rigour and further investigation into the potential health risks of meat consumption, particularly processed meat. They also acknowledge the lack of clear causal relationships between meat intake and cardiovascular disease.

Evidence from systematic reviews and meta-analyses of randomised controlled trials

The evidence on red meat's role in CVD largely comes from observational studies, with fewer gold standard randomised control trials (RCTs) available. More RCTs are needed to provide clearer insights and confirm cause-and-effect relationships. Below are some key findings from the existing RCT research.
A series of meta-analyses and randomised controlled trials (RCTs) have investigated the effects of red and processed meat consumption on cardiovascular disease (CVD) and potential risk markers, with mixed findings that highlight the complexity of this relationship and the need for further research.[95,96,98]

One meta-analysis of 24 RCTs, which involved consumption of varying amounts of red and processed meat, found no significant effects on blood pressure or blood lipid levels, even at high meat intake levels (up to three servings per day).[95] The studies, which ranged from 2 to 32 weeks in duration, showed that diets with more than 3.5 servings of meat per week did not lead to increased CVD risk factors compared to diets with little or no meat. This suggests that, in the short to medium term, higher meat consumption may not be as strongly linked to CVD risk as previously thought.

Similarly, a systematic review of 12 RCTs[96], including large-scale studies such as the Women's Health Initiative[97], found that reducing red meat intake had little to no impact on cardiometabolic outcomes or the incidence of CVD and stroke. Specifically, a reduction of three servings of red or processed meat per week did not significantly alter health outcomes related to CVD. The evidence quality was rated as low, underscoring uncertainty about the long-term effects of red meat reduction on heart health. These findings stand in contrast to current public health recommendations that suggest reducing red meat intake to lower CVD risk.

Finally, a meta-analysis of 36 RCTs comparing red meat diets with replacement diets (including plant proteins, fish and poultry) found no major differences in cardiovascular risk markers between diets that included red meat and those that replaced it with other animal or plant-based proteins.[98] Interestingly, replacing red meat with high-quality plant proteins, such as legumes and soy, led to more favourable changes in blood lipids and cholesterol levels compared to diets that replaced red meat with fish or low-quality carbohydrates. This suggests that while replacing red meat with plant-based options may provide benefits for heart health, the effect of red meat alone on CVD risk remains unclear.

Taken together, these studies indicate that red and processed meat consumption may not have as strong or direct an impact on CVD risk as once assumed, particularly when compared to the benefits of replacing meat with plant-based proteins. However, the mixed results and varying study designs point to the need for more well-controlled, long-term RCTs to better understand the complex relationship between meat consumption and cardiovascular health.

Summary – Research findings for red meat and CVD risk

Observational studies suggest processed meat is more strongly associated with CVD risk than red meat, with a small increase in risk linked to consuming 50 g of processed meat per day. Reducing meat intake by three servings per week (where one serving of red meat is equivalent to 120 g processed meat, to 50 g or a mixture of both at 100 g) may slightly lower CVD risk, though the evidence is of low certainty and the risk reduction minimal.[87] The PURE study found no clear link between red meat consumption (≥250 g versus <50 g per week) and CVD events, but it did find an association between processed meat intake (>150 g versus 0 g per week) and increased CVD events (46%) and mortality (51%).[89]

Umbrella reviews of observational studies found no clear associations between red or processed meat intake and CVD risk, though moderate evidence suggests higher processed meat intakes may increase risk.[91] No review found 'convincing' or 'probable' evidence linking meat consumption to CVD, CHD, T2D or cancer, but some identified 'possible' links with stroke and CHD risk.[92] One umbrella review combining observational and RCT data found weak associations with CVD for all meat types .[93] All reviews stressed the need for high-quality research as observational studies suffer from bias and inaccuracies, particularly due to reliance on food frequency questionnaires.

While observational studies suggest a link between meat consumption and CVD, the limited RCT evidence makes it difficult to confirm causal relationships. Meta-analyses of RCTs show minimal to no effect of meat consumption on CVD risk.[95,96,98] One meta-analysis of 24 RCTs found no significant differences in blood pressure or lipid levels between high and low meat intake[95], while others reported little impact of reducing red meat on cardiometabolic outcomes.[96] Additionally, a meta-analysis of 36 RCTs found no significant differences in CVD markers between diets with red meat and those replacing it with other foods, though diets with high-quality plant proteins had more favourable effects on blood lipids.[98] Similarly, an umbrella review of RCTs examining mixed red and processed meats found mostly non-significant results, with little consistency between RCT and observational findings and no evidence supporting a causal relationship to CVD.[93]

While observational studies suggest a link, RCT findings are more complex. The limitations of RCTs – such as difficulty in blinding participants and selecting suitable controls and measuring disease markers over short study periods – highlight the need for long-term, high-quality studies to clarify red meat's potential association with CVD risk.
Moreover, considering the impact of 'other' foods on CVD risk is crucial[86], as factors like whole grains, fruits, vegetables, nuts and fish may protect against CVD[23], while sugar-sweetened beverages may increase the risk. Given these complexities and current health recommendation to reduce red and processed meat intake[23,28], targeting higher consumers (>90 g/day) for reductions and emphasising healthier meat choices in dietary guidelines is essential.

Red meat and type 2 diabetes

Type 2 diabetes

In the UK ~4.3 million people have diabetes, with 90% diagnosed with type 2 diabetes (T2D) and 8% with type 1.[10] Over 2.4 million people are at high risk of developing T2D, which is increasingly common in those under 40 years old, especially in deprived areas. T2D raises the risk of serious health conditions, like heart disease and stroke. Risk factors include age, family history and being overweight or obese, with 64% of adults in England falling into the latter category.[10]

Diabetes (*Diabetes mellitus*) is a condition where blood glucose levels rise because glucose, a breakdown product from carbohydrate consumption, cannot enter cells to fuel the body. This occurs when the body produces no insulin (type 1 diabetes), insufficient insulin or ineffective insulin (T2D). Without effective or the right amount of insulin, glucose builds up in the blood, leading to health problems. In healthy individuals without diabetes, the pancreas releases the correct amount of insulin to regulate glucose levels.[99]

Diet plays a key role in the risk of developing T2D. Diabetes UK provides guidelines for prevention and management of T2D, emphasising healthy eating, physical activity and weight loss. Recommendations for reducing T2D risk include restricting energy intake, reducing total and saturated fat intake, increasing fibre intake and engaging in physical activity.[100] Specific foods linked to lower T2D risk are wholegrains, fruits, leafy vegetables, low-sugar yogurt and cheese. Conversely, red and processed meat, potato French fries, sugar-sweetened beverages and refined carbohydrates should be limited.[100,101] Research evidence from observational studies show that reducing red and processed meat consumption is associated with lower T2D risk.[102,103,104] Weight loss, of 5–7%, is the most effective strategy to reduce the risk (RR) of T2D by 50%.[105] Given that being overweight or obese is a major driver of T2D, and with high obesity rates in the UK (26% obese and 38% overweight)[2], weight management is crucial as global rates are rising alongside T2D prevalence.[6]

The link between type 2 diabetes and red meat

Observational studies have explored the link between red and processed meat consumption and the risk of T2D, with RCTs seeking to confirm causality by examining glycaemic control markers. While observational research is more abundant than RCT data, this section of the report reviews both types of studies in more detail. Accurate periodic dietary intake data is essential to reduce bias, particularly given the impact of glucose levels on T2D risk.

The most recent research in the area is briefly summarised and presented in hierarchical order, with relevant relative risk (RR) or hazard ratio (HR) summarised in Table 7.

Observational research: Systematic reviews and meta-analyses linking red meat to type 2 diabetes

A large prospective study (EPIC-Interact EU study) with 15,258 participants across eight European countries examined the link between meat consumption and type 2 diabetes (T2D).[104] After 11+ years, a follow-up showed higher total meat consumption (including red meat, poultry, processed meat and offal) and red meat alone were both associated with an 8% increased T2D risk (HR 1.08). Processed meat specifically was linked to a 12% higher T2D risk (HR 1.12) per 50 g daily increment. Interestingly, gender-specific analyses showed stronger associations with red and processed meat consumption in men, with weaker or non-significant results for women. Poultry intake was associated with a 20% increased T2D risk with hazard ratio of 1.20, but this increased risk was associated with women. The study emphasised that findings may not be generalisable outside the EU due to regional dietary differences, an important consideration when comparing data globally. Interestingly, a further meta-analysis of 31 cohort studies including ~2.2 million participants examined associations between unprocessed red and processed meat consumption and cardiometabolic outcomes including T2D.[87] This study found “very low certainty” that reducing unprocessed red meat by three servings per week would reduce T2D risk (RR 0.90). Similarly, processed meat reduction by 22% was linked to a 22% risk reduction (RR 0.78), but authors of the study concluded that quality of the evidence was low due to flaws in study design. Finally, a meta-analysis of 15 cohort studies from across Europe, US and Asia found that high red meat intake was linked to a 15% higher T2D risk (RR 1.15), and processed meat consumption was associated with a 27% higher risk (RR 1.27).[106] Regional differences showed stronger associations in US cohorts, with less consistent findings in Europe and Asia. Limitations included reliance on baseline dietary data and self-reported T2D diagnoses.

Table 7. Summary of relative risk and hazard ratio reported in T2D observational research

Research paper	Research type	T2D risk assessment	Increased risk
Interact Consortium (2013)[104]	Dose-response meta-analysis	Total meat and T2D (50 g/day)	HR 1.08 (95% CI: 1.05–1.12)
		Red meat and T2D (50 g/day)	HR 1.08 (95% CI: 1.03–1.13)
		Processed meat and T2D (50 g/day)	HR 1.12 (95% CI: 1.05–1.19)
		Poultry meat and T2D (50 g/day)	HR 1.20 (95% CI: 1.07–1.34)
Zhang et al. (2021)[106]	Dose-response meta-analysis	Higher processed red meat intake (high vs low intake)	RR 1.27 (95% CI: 1.15-1.40)
		Higher unprocessed red meat intake (high vs low intake)	RR 1.15 (95% CI: 1.08-1.23)
Neuenschwender et al. (2019)[107]	Dose-Response Meta-Analysis	T2D and red meat (100 g/day)	HR 1.17 (95% CI: 1.08-1.26)
		T2D and processed meat (50 g/day)	HR 1.37 (95% CI: 1.22-1.54)

Notes: **Relative risk (RR)** Is the likelihood of an event occurring in a group of people compared to another group.[33] An RR <2.0 is considered to have too much risk of confounding.[46]
95% confidence interval (CI) represents the level of confidence in the findings, which lies between the two values.
Hazard ratio (HR) is used when measuring chronic conditions or long-term outcomes it describes survival over time.[44]

Umbrella reviews of observational studies linking red Meat to T2D

Several umbrella reviews and meta-analyses have explored the relationship between meat consumption and the risk of type 2 diabetes (T2D). Neuenschwender et al. (2019)[107] carried out an umbrella review of 53 different cohort studies and found that higher red meat intake, at 100 g per day increments, was associated with a 17% increase in T2D risk (HR: 1.17), while processed meat consumption at 50 g per day increments was linked to a 37% higher risk (HR: 1.37). Notably, bacon consumption (two slices per day) was associated with a 107% increased risk (HR: 2.07). The quality of evidence was considered high for these associations. Conversely, increased whole grain intake of 30 g per day was inversely associated with T2D risk (HR: 0.87), supporting SACN recommendations to consume more fibre to decrease T2D risk.[28] A more recent umbrella review assessed 59 meta-analyses (399 articles) on total, red and processed meat and various health outcomes, including T2D.[92] The findings showed “limited” evidence linking red and processed meat consumption to T2D risk, with significant heterogeneity and potential confounding factors across studies. There was no “convincing” or “probable” evidence for an association, though it was highlighted that excess meat intake may still pose health risks, but the review could not give a clear indication of recommended intake quantities.

A third umbrella review examined 29 systematic reviews and meta-analyses (observational and RCTs) for the risks of red and processed meat consumption on T2D and cardiovascular disease (CVD) .[93] Observational studies showed strong associations between processed meat and a combination of both red and processed meat consumption and increased T2D risk. However, experimental RCTs found mostly non-significant results, indicating that the relationship between red meat and T2D remains unclear. The review concluded that while causality between red and processed meat and T2D has not been definitively established, there is potential for a causal link, particularly with processed meats. It was clearly highlighted that more RCTs are needed, particularly on processed meat, to confirm these findings. In summary, while the evidence linking red and processed meat to T2D is mixed, high intake of these meats, especially processed varieties, is associated with a higher risk of T2D. However, due to study heterogeneity and confounding factors, further research is needed to clarify the strength and causality of these associations.

Systematic reviews and meta-analyses of randomised controlled trials linking red meat to T2D

The effects of red meat intake on glycaemic control and markers of T2D inflammation among adult men and women at risk of T2D or cardiovascular disease was assessed via a meta-analysis and dose response meta-regression of 20 different RCTs.[108] Chronic inflammation-induced insulin resistance is a proposed mechanism for associations between red meat intake and the risk of T2D.[109,110] Compared to diets with less than 0.5 servings (35 g) of red meat per day, higher red meat consumption (more than 490 g per week) had no effect on blood glucose, insulin levels or inflammatory markers (e.g. C-reactive protein and cytokines) over 16 weeks. Subgroup analysis also showed no benefit from replacing red meat with other animal or plant-based proteins (e.g. poultry or soya). These results were consistent across studies deemed of fair to good quality.

A meta-analysis of 21 RCTs, by Sanders and colleagues (2023)[111], focused on red meat (beef, pork and lamb) consumption versus lower or no red meat intake. The study found that red meat had no significant impact on glycaemic markers, such as insulin sensitivity, fasting glucose, HbA1C or pancreatic function. However, in a subgroup of adults with T2D, red meat diets slightly improved insulin sensitivity and lowered fasting glucose. The quality of evidence was rated low to moderate, and the authors called for more research to clarify the relationship between red meat and glucose metabolism.

Interestingly, a slightly different approach was taken in a systematic review of 12 RCTs, which looked at the effects of reducing red and processed meat (three servings per week) on cardiometabolic outcomes[96], including T2D. The study found limited evidence, suggesting that lowering red meat intake had little to no impact on T2D or other non-communicable diseases (NCDs). While questioning the <70 g/day health recommendation for red and processed meat, the authors noted that the evidence quality was low to very low and emphasised the need for more research to clarify the potential causal links.

These findings have also been corroborated by the one umbrella review of 29 systematic reviews and meta-analyses assessing the link between red and processed meat intake and T2D risk.[93] Findings from seven RCTs showed insufficient evidence for a clear role of unprocessed red meat in T2D risk, and RCT results for mixed red and processed meat were mostly non-significant. The review concluded that while there may be a potential causal link between meat consumption and T2D, more RCTs, particularly on processed meat, are needed to confirm or refute these findings.

The overall conclusion is that red meat has shown neutral effects on glycaemic control and T2D risk markers in most studies. While some studies suggest potential marginal improvements in T2D outcomes with reduced red meat intake, the evidence remains inconsistent and of low quality. More high-quality research is needed to establish any causal relationship between red meat consumption and T2D.

Brief summary – Research findings for red meat and type 2 diabetes risk

While observational research findings suggest an association between meat consumption and the risk of T2D, particularly for processed meats, meta-analyses of RCTs do not provide sufficient evidence of causality. Clear and standardised definitions and robust methodologies are needed to better understand these relationships and inform dietary guidelines for T2D prevention and treatment. Individuals who consume >90 g of red and processed meat per day should be supported in reducing their intake, in line with the Eatwell Guide, which emphasises the importance of overall dietary patterns in prevention of T2D and other NCDs.

Reassessing the impact of red meat on health: A critical need for action

Recent research has questioned the strength and sufficiency of evidence linking red meat consumption to NCD risks, arguing that the findings are too weak to draw any definitive conclusions.[76, 112–115]

The Global Burden of Disease study

The 2019 Global Burden of Disease (GBD) study, published every 2–4 years in The Lancet, provides comprehensive data on global health trends, including estimates of mortality and disease linked to dietary risk factors[116–118]. Notably, the 2019 report[117] significantly revised previous findings on the impact of dietary risks.[116] Compared to the 2017 report, deaths and disability-adjusted life years (DALYS) attributed to diets high in salt and low fruits, nuts, vegetables or omega-3 fatty acids were halved while those linked to diets low in legumes and high in processed meats and trans fats more than doubled.

The most striking revision was in the attribution of global deaths and DALYs to unprocessed red meat. The 2017 GBD report linked unprocessed red meat to 25,000 deaths and 1.3m DALYs, primarily to colorectal cancer and diabetes. However, the 2019 report expanded the evidence to include additional risks such as ischaemic heart disease, breast cancer and stroke, suggesting even very low intakes of red meat are harmful and that the theoretical minimum risk exposure level (TMREL) for unprocessed red meat was zero grams daily. As a result, the 2019 estimates attributed 896K deaths and 23.9m DALYs to unprocessed red meat, representing 36 and 18-fold increases over the 2017 figures, respectively. These revised estimates were based on new systematic reviews, and meta-regressions, which had not yet been peer-reviewed or assessed for certainty.

The dramatic revisions in the GBD 2019 study[119] prompted concerns about the reliability of the findings. Researchers requested PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)-compliant reports for the new systematic reviews[112], and organisations including the World Cancer Research Fund (WCRF) and the Academy of Nutritional Sciences (ANS) [113] called for clarification on the zero-gram TMREL for unprocessed red meat. In response, the authors of the 2019 GBD study acknowledged that “setting of the TMREL for red meat to zero was incorrect” and stated that future GBD analyses will revise the estimates for deaths attributable to red meat consumption.[117]

It was welcomed that the GBD 2021 Risk Factors Study[118] reported a two-thirds reduction in deaths to 334K deaths and 9.6m DALYs. While the estimates for other dietary risk factors also shifted, these revisions were based on new systematic reviews and updated modelling methods. However, concerns remain as peer-reviewed, PRISMA-compliant reports have only been published for red meat and vegetable consumption – but no reports for the other 19 dietary risk factors. Additionally, 38 of 44 associations between dietary risk factors and adverse outcomes were rated as weak evidence of association (2 stars) or inconclusive with no evidence of association (1 star), with many risk curves not statistically significant. Researchers have subsequently questioned the validity of including such uncertain non-significant relationships in mortality and DALYs estimates attributed to dietary risk factors.[120]

Despite the revised 2021 GBD publication, the 2019 GBD data continues to influence global research policies and reports, including the UK’s National Food Strategy[121] and the Eat-Lancet Commission.[122] The National Food Strategy, using 2019 GBD data, claims red and processed meat contribute to four times as many illnesses as diets high in salt[121], while the Eat-Lancet Commission calls for a >50% worldwide reduction in red meat consumption, based on inflated risk estimates from the 2019 GBD report. The National Food Strategy and Eat-Lancet 2019 reports have been widely cited, with the Eat-Lancet article alone referenced over 6,178 times. Given the recognised errors in the 2019 GBD data[117], caution is advised when using these findings in future policy revisions and recommendations.

The Nutritional Recommendations (NutriRECS) Consortium

The Nutritional Recommendations (NutriRECS) Consortium, comprising 14 members from seven countries, conducted five systematic reviews to assess the health impacts of red and processed meat consumption and consumer preferences.[114] Their aim was to provide evidence-based dietary guidelines for red and processed meat consumption related to cardiometabolic and cancer outcomes.[114] Four reviews focused on the effects of red and processed meat consumption on health, using data from 12 RCTs (54,000 participants) and 40 cohort studies (~3.6 million participants). The fifth review examined consumer values based on 54 research studies (41 quantitative and 13 qualitative), establishing that red and processed meat is typically consumed two to four times per week in North America and Europe.

Following a rigorous systematic review, the Nutritional Recommendations (NutriRECS) international consortium developed and applied GRADE system methods to assess the certainty of evidence on red meat consumption and its health impacts. They found that reducing red meat consumption by three servings per week (i.e. from seven to four servings or four to one serving) may have minimal effects on reducing risks for cardiometabolic diseases (CVD, stroke and T2D) and cancer mortality, based on low certainty evidence.

Observational studies found that reducing processed meat consumption may slightly decrease the risk of major cardiometabolic events (CVD, stroke, heart attacks and T2D) and certain cancers, including colorectal cancer, though with a low to very low certainty of evidence. The panel concluded that meat consumption is unlikely to be a major causal factor in adverse health outcomes, as its effects are smaller than those from other dietary patterns, such as those high in salt, saturated fat and excess calories. Regarding consumer preferences, most consumers are reluctant to reduce their meat intake, citing its importance as part of a healthy diet for protein, enjoyment and limited cooking skills. Those who had already reduced meat intake had no intention to cut down further. While some consumers are sceptical about the health risks, they perceive these as less significant than those associated with smoking and cancer. Concerns about animal welfare or the environment were minimal. The panel recommended that those considering reducing meat consumption should be informed of the scientific evidence relating to any associated risks.[114]

The panel concluded that most adults can continue consuming red meat at current levels as there is insufficient evidence to suggest health risks from higher intake, particularly regarding colorectal cancer. They acknowledged that their findings differ from current health recommendations,[23, 30–31] citing uncertainty around the potential harmful effects of red meat consumption and the likelihood of confounding factors. The panel issued a weak recommendation for people to maintain their current meat intake, noting that even if red meat has a small causal effect, it is unlikely to be significant.

The NutriRECs panel recommends maintaining current red and processed meat intake[114], which averages 63 g per day for adults aged 19+.[64]

The Burden of Proof studies

Risk exposure throughout life leads to various health outcomes, making it essential to understand its true impact on both personal and societal health. However, as demonstrated throughout this report, methods to quantify and rank disease risk often suffer from methodological flaws and subjective interpretation. The Burden of Proof (BoP) studies used meta-analyses to evaluate the impact of different risks on public health outcomes like smoking and cancer.[123] The researchers developed a data-driven methodology, the Burden of Proof Risk Function (BoPRF), to adjust for biases and evaluate the relationship between exposure and disease outcomes. This system, complementing GRADE and Cochrane reviews, assigns a star rating from 1 to 5, denoting the strength of evidence as ‘no’, ‘weak’, ‘moderate’, ‘strong’ or ‘very strong’.

One of the four meta-analyses in the BoP research assessed the epidemiological evidence on the impact of unprocessed red meat consumption on six health outcomes [Ischaemic heart disease (IHD), ischaemic and haemorrhagic stroke, colorectal cancer, breast cancer and T2D][115], using data from 55 studies across four continents (North America, Europe, Asia and Australia) involving up 2.4 million participants. The BoPRF methodology found no or very weak evidence linking red meat to increased risk. Specifically, it identified a weak association with colorectal cancer, breast cancer, CHD and T2D, with risk increases of 6%, 3%, 1% and 1%, respectively, earning a 2-star rating for strength of evidence.

Using colorectal cancer (6%) as an example, earlier studies found a 30% increased risk with 50 g of red meat daily (RR 1.30) 95% UI: 1.01–1.64) and a 37% increased risk with 100 g (RR 1.37 (95% UI:1.01–1.78)). However, after applying the BoPRF methodology,[123] the risk was recalculated to be 6% for red meat consumption, (0–98 g/day) with a relative risk ratio of 1.06. This resulted in a weak evidence rating (2 stars), reflecting minimal association.

The authors concluded that while avoiding red meat may reduce disease and mortality risk, the evidence is too uncertain to make definitive claims. They noted significant heterogeneity between studies and emphasised the need for more rigorous, well-powered research studies to better understand the link between red meat consumption and chronic disease.

The importance of using accurate dose-response meta-analysis methods for reliable health risk assessment

Observational studies, particularly dose-response meta-analyses, of diet and NCDs are susceptible to confounding.[125, 126] Traditional models often overestimate risk by assuming a simple linear relationship between dose and outcome, especially at low consumption levels. These models are also vulnerable to measurement errors and bias when combining data from diverse populations, leading to inaccurate conclusions.

Newer empirical models based on real-world data offer more flexibility accounting for non-linear relationships and changes over time. These models are believed to provide more accurate estimates than traditional does-response meta-analyses, which can be biased.[128] Researchers comparing red and processed meat intake and colorectal cancer risk used both traditional and empirical models[124], analysing data from large prospective cohort studies (red meat ~17.26 million person-years: processed meat ~23.52 million person-years), to test the dose-response relationships at varying consumption levels.

Using the most up-to-date empirical dose-response models, no significant association was found between 50 g per day of red meat and colorectal cancer (RR 0.93 (95% CI:0.8-1.02)), nor at any other consumption level (RR 1.04 (95% CI:0.99–1.10)). In contrast, traditional models suggested a 9% increased risk of colorectal cancer RR 1.09 (95% CI:1.00–1.18), likely due to the incorrect application of a linear relationship between low and high consumers. Similarly, 20 g per day of processed meat showed no significant link to colorectal cancer in empirical models (RR 1.01) (RR 1.01 (95% CI:0.87–1.18), while traditional models overestimated risk at low consumption levels (RR 1.07 (95% CI:1.02–1.12)).

Researchers concluded that traditional models may overestimate risk by assuming a linear relationship between consumption and disease risk. They found no significant link between red or processed meat and colorectal cancer at lower consumption levels (i.e. below median US consumption levels), especially when excluding high consumers data. They emphasised the need for more accurate dose-response methods in observational research, particularly for developing dietary guidelines. Given these findings, moderate meat consumption as part of a healthy, balanced diet appears less concerning, especially in the UK, where current guidelines recommend no more than 70 g per day of red and processed meat[31] and consumers on average eat less (63 g/day).[64] However, it remains important to support high consumers in reducing red and processed meat intake to align with the UK government's dietary recommendations.

Challenges in communicating the evidence on red meat consumption and NCD risk

The evidence linking red meat consumption to NCD risk is mixed and often confounded by stronger associations with processed meats. Misleading interpretations such as the IARC's reported 18% higher risk of colorectal cancer from processed meat can fuel sensational media headlines and disproportionate criticism of red meat. These oversimplifications neglect red meat's role in a healthy, balanced sustainable diet and farmers' efforts to improve environmental practices. The media often focus on individual foods or nutrients creating confusion by either demonising or glorifying specific items. It is essential to interpret scientific research findings within the context of the hierarchy of evidence. To accurately understand the risks, it is crucial to consider research within the broader context of overall dietary patterns and health and the evolving nature of the scientific evidence.

Summary and conclusion for the scientific evidence for red meat consumption and NCD risk

Overview:

The World Health Organization (WHO) highlights that a healthy diet helps prevent malnutrition and NCDs such as diabetes, heart disease, stroke and cancer.[1] In the UK, less than 1% of the population follows the Government's healthy Eatwell Guide recommendations[22, 23], and over a third of adults in England are overweight (38%) or obese (28%).[2] Additionally, one in three adults do not meet physical activity recommendations.[8] Food insecurity affects 11.3 million people (14% of UK adults), contributing to malnutrition and widening health inequalities.[14] These factors increase the risk of developing NCDs. While red and processed meat consumption is linked to higher risks of colorectal cancer, CVD and T2D, especially for processed meats, systematic reviews and meta-analyses of observational studies often show positive associations. More robust RCTs and umbrella reviews tend to report minimal or no significant impact, suggesting that the health risks may not be as pronounced as observational studies indicate.

Since 2010, UK health guidelines recommend limiting red and processed meat to a maximum of 500 g/week (70 g/day cooked weight) due its association with increased colorectal cancer risk.[31] Those consuming more than 90 g per day are advised to reduce intake to 70 g or less. Diabetes UK also notes that red and processed meat may increase the risk of T2D, based on observational data (from three prospective cohort studies).[100, 101] For CVD disease prevention, the focus is on a healthy, balanced diet, with fewer calories, saturated fat, salt and sugar, alongside increased physical activity.[82]

Concerns with research methodology

Research examining the health effects of red and processed meat consumption on NCD risk and mortality is complex and inconsistent. Systematic reviews and meta-analyses of observational studies show mixed results, with some linking red meat to NCD risk while others do not. When associations are found, their strength varies widely, partly due to the limitations of observational studies, which can only show associations, not causation, yet they have been used to inform dietary guidelines to limit red and processed meat consumption.[7, 31, 23]

These studies are prone to increased bias and confounding [46, 130], and weak associations may lead to false positives, as seen with the IARC report on colorectal cancer and processed meat.[61] The lack of context in risk communication can amplify findings and create confusion, making it essential to present risk in absolute terms to help consumers make informed health choices. While RCTs provide stronger evidence for causality, they also have limitations, such as issues with dietary compliance, large participant dropouts, shorter follow-up duration and unaltered disease risk markers[96, 98], limiting their ability to detect long-term health outcomes like CHD, T2D and cancer. Additionally, the effects of reduced meat intake may vary depending on the alternative protein replacement, (fish, chicken, whole grains or refined carbohydrates can have different health impacts).[131–133]

Research also suffers from inconsistent definitions for red and processed meats, leading to discrepancies.[83] An umbrella review found that 27 studies[93] misclassified meats due to unclear distinctions in processing levels. Standardised definitions and longer-duration RCTs are needed to clarify the cause-and-effect relationship between red meat consumption and NCDs.[134] To improve the reliability of dietary guidelines and health recommendations, more robust, long-term research is essential.

Scientific re-evaluation and risk communication

Some scientists have identified significant weaknesses in studies linking red meat consumption to NCDs[76, 112–115], suggesting that health risks may be overestimated and moderate consumption may pose lower risks than previously thought. Future research should re-evaluate existing data using improved modelling, conduct comprehensive longitudinal studies and incorporate real-world dietary patterns to develop precise evidence-based nutritional guidelines.

Communicating red meat's health risks is challenging due to mixed findings, stronger links to processed meats and media oversimplification. The benefits of red meat such as its high-quality protein and essential micronutrients (iron, B12, zinc and selenium) are often overlooked, and climate change concerns add complexity. Clear communication requires careful consideration of dietary patterns, evidence quality and the evolving nature of scientific research to balance health and environmental needs.

Understanding red meat consumption and NCD risks in context

Red meat consumption in the UK is declining while poultry sales rise. At the same time, the popularity of ready meals and convenience foods, higher in calories, saturated fat, salt and sugar, is increasing. While many consumers stay within the recommended limit of <70 g/day of red and processed meat, a smaller group, particularly men, exceed this (>90 g/day).[64] However, UK red meat intake is still lower than many other EU countries.[104] Beyond meat consumption, the UK faces a broader health crisis, with rising health inequalities, poor diets lacking fruits, vegetables and whole grains, and sedentary lifestyles contributing to increased obesity and NCD risks. Poor mental health stress healthcare access also impacts health, leading to unhealthy choices and worse health outcomes. Focusing solely on red meat consumption as a primary risk for NCDs oversimplifies the issue. A more holistic approach is required to address the broader determinants of population health, with government action essential to improve public health and reduce NCD risks.

Future approaches to help mitigate against NCD risks

Given research linking red meat consumption to NCD risk, alongside broader concerns like poor diet, low physical activity and rising obesity rates in the UK, it is important to address these risks. Striking a balance between red meat's nutritional benefits and health risks requires careful consideration, not strict limitation. UK guidelines recommend limiting red and processed meat to 70 g per day[7, 23, 31], a target many consumers already meet.[64] The focus should be on those consuming over 90 g per day, encouraging adherence to the Eatwell Guide for consumption of a healthier and more sustainable diet.

A Food Standards Scotland study modelling the 20% meat reduction target by 2030[66] found that that limiting red and processed meat to less than 70 g per day could reduce meat consumption by 16% and improve health outcomes like BMI, cardiovascular health and T2D rates.[65] However, excessive reductions could negatively impact micronutrient intake, especially in vulnerable groups. Further reductions may be possible but require additional analysis, as the CCC target includes all meats, including poultry.[65] Funding for long-term, high-quality RCTs is essential to clarify causal links between red and processed meat consumption and NCDs and guiding dietary recommendations. Standardising meat definitions, strengthening dietary guidelines and monitoring dietary trends will help reduce health inequalities and support public health goals.

Overall conclusions

The UK's current health landscape is marked by rising overweight and obesity rates and increasing incidences of NCDs, driven by poor diet, low physical activity and growing health inequalities. While red and processed meat consumption is linked to higher NCD risks, evidence is mixed and sometimes inconclusive, suggesting a potential overestimation of risk. More rigorous long-term studies are necessary to better understand the health impacts of eating red and processed meat.

References

1. World Health Organization (WHO). (2020). Healthy Diet. Available at: **https://www.who.int/news-room/fact-sheets/detail/healthy-diet** (Accessed: 10th April 2024).
2. House of Commons Library. (2023). Obesity Statistics. Available at: **https://researchbriefings.files.parliament.uk/documents/SN03336/SN03336.pdf** (Accessed 27th April 2024).
3. Bell, M. and Deyes, K. (2022), 'Estimating the full costs of obesity: a report for Novo Nordisk', Frontier Economics Report, 26 January 2022
4. Lin, X., Li, H. (2021). Obesity: Epidemiology, Pathophysiology, and Therapeutics. Frontiers in Endocrinol (Lausanne), 12: 706978.
5. Powell-Wiley, T.M., Poirier, P., Burke, L.E., Després, J.P., Gordon-Larsen, P., Lavie, C.J., Lear, S.A., Ndumele, C.E., Neeland, I.J., Sanders, P., St-Onge, M.P.; American Heart Association Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; Council on Epidemiology and Prevention; and Stroke Council. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation. 2021 May 25;143(21):e984-e1010.

6. Klein, S., Gastaldelli, A., Yki-Javinen, H. et al. (2022). Why does obesity cause diabetes? Cell Metabolism, 34(1): 11-20.
7. World Cancer Research Fund American Institute for Cancer Research (WCRF/AICR). Continuous Update Project (CUP) Expert Report (WCRF/AICR). (2018). Meat, fish and dairy products and the risk of cancer. Available at: https://www.wcrf.org/wp-content/uploads/2021/02/Meat-fish-and-dairy-products.pdf (Accessed 8th July 2023).
8. British Heart Foundation. (2024). UK Factsheet. Available at: **https://www.bhf.org.uk/-/media/files/for-professionals/research/heart-statistics/bhf-cvd-statistics-uk-factsheet.pdf** (Accessed 8th April 2024).
9. MacMillan Cancer Support. (2024). Cancer statistics in the UK. Available at: **https://www.macmillan.org.uk/about-us/what-we-do/research/cancer-statistics-fact-sheet** (Accessed 8th April 2024).
10. Diabetes UK. (2024). Number of people living with diabetes in the UK tops 5 million for the first time. Available at: **https://www.diabetes.org.uk/about-us/news-and-views/number-people-living-diabetes-uk-tops-5-million-first-time** (Accessed 8th April 2024).
11. Age UK. (2024). Malnutrition. Available at: **https://www.ageuk.org.uk/information-advice/health-wellbeing/conditions-illnesses/malnutrition/** (Accessed 4th April 2024).
12. Kiosia, A., Dagbasi, A., Berkley, J.A. et al. (2024). The double burden of malnutrition in individuals: identifying key challenges and re-thinking research focus. Nutrition Bulletin, 49(2): 132-145.
13. Kobylińska, M., Antosik, K., Decyk, A. et al. (2022). Malnutrition in obesity: is it possible? Obesity Facts, 15(1): 19-25.
14. Trussel Trust. (2024). Hunger in the UK. Available at: **https://www.trusselltrust.org/wp-content/uploads/sites/2/2023/08/2023-The-Trussell-Trust-Hunger-in-the-UK-report-web-updated-10Aug23.pdf** (Accessed 8th April 2024).
15. House of Commons Library. (2022). Food bank demand and the rising cost of living. Available at: **https://commonslibrary.parliament.uk/food-bank-demand-and-the-rising-cost-of-living/ (**Accessed 2nd June 2024).
16. Hanson, K.L. and Connor, L.M. (2014). Food insecurity and dietary quality in US adults and children: a systematic review. American Journal of Clinical Nutrition, 100(2): 684-692.
17. Oberle, M.M., Romero Willson, S., Gross, A.C. et al. (2019). Relationships among child eating behaviors and household food insecurity in youth with obesity. Childhood Obesity, 15(5): 298-305.
18. Carvajal-Aldaz, D., Cucalon, G., Ordonez, C. (2022). Food insecurity as a risk factor for obesity: a review. Frontiers in Nutrition, 26(9): 1012734.
19. Blackburn, J.Y.E., Bres, H., Devenish, G. et al. (2021). 888-P: Food insecurity and type 2 diabetes in children: a systematic literature review. Diabetes, 70(Supp1): 888–P.
20. Levi, R., Bleich, S.N., Seligman, H.K. (2023). Food insecurity and diabetes: overview of intersections and potential dual solutions. Diabetes Care, 46(9): 1599-1608.
21. Chang, R., Javed, Z., Taha, M. et al. (2021). Food insecurity and cardiovascular disease: current trends and future directions. American Journal of Preventive Cardiology, 10(9): 100303.
22. Scheelbeek, P., Green R, Papier, K., Knuppel, A., Alae-Carew, C., Balkwill, A., Key, TJ., Beral, V., Dangour, AD. (2020). Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: analyses of multiple UK studies. *BMJ Open*. 10(8):e037554.
23. Public Health England. (2018). A quick guide to the government's healthy eating recommendations https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/742746/A_quick_guide_to_govt_healthy_eating_update.pdf (Accessed 8th July 2023).
24. Public Health England. (2020). NDNS: results from years 9 to 11 (2016 to 2017 and 2018 to 2019). https://www.gov.uk/government/statistics/ndns-results-from-years-9-to-11-2016-to-2017-and-2018-to-2019 (Accessed 14th July 2023)
25. Scotttish Health Survey (SheS). (2024). Scottish Health Survey Collection. Available at: **https://www.gov.scot/collections/scottish-health-survey/** (Accessed 10th April 2024).

26. Department for Environment, Food and Rural Affairs. (2022). National Statistics – Family Food 2020/21: Annual report on household purchases of family food and drink. Available at: **https://www.gov.uk/government/statistics/family-food-202021** (Accessed 10th April 2024).
27. World Health Organization (WHO). (2023). Noncommunicable diseases. Key facts. Geneva, WHO. Available at: **https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases** (Accessed 27th April 2024)
28. SACN (Scientific Advisory Committee on Nutrition). (2015). Carbohydrates and health. Available at: **https://assets.publishing.service.gov.uk/media/5a7f7cc3ed915d74e622ac2a/SACN_Carbohydrates_and_Health.pdf** (Accessed 14th June 2024).
29. Nordhagen, S., Beal, T. and Haddad, L. (2020). The role of animal-source foods in healthy, sustainable, and equitable foods systems. Global Alliance for Improved Nutrition (GAIN). Discussion Paper #5. Geneva, Switzerland.
30. World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR). (2007). Food, nutrition, physical activity, and the prevention of cancer: a global perspective. Washington DC: AICR.
31. SACN (Scientific Advisory Committee on Nutrition). (2010). Iron and health. Available at: **https://assets.publishing.service.gov.uk/media/5a7df3dd40f0b62305b7fd53/SACN_Iron_and_Health_Report.pdf** (Accessed 26th October 2023).
32. International Agency for Research on Cancer (IARC). (2015b). Q&A on the carcinogenicity of the consumption of red and processed meat. Available at: **https://www.iarc.who.int/wp-content/uploads/2018/11/Monographs-QA_Vol114.pdf** (Accessed 16th April 2024).
33. EUFIC (European Food Information Council). (2017b). Absolute risk vs. relative risk: what's the difference? Available at: Absolute Risk vs. Relative Risk: What's the Difference? | Eufic (Accessed 19th July 2024).
34. Shea, B.J., Grimshaw, J.M., Wells, G.A. et al. (2007). Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Medical Research Methodology, 7: 10.
35. Shea, B.J., Reeves, B.C., Wells, G. et al. (2017). AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. British Medical Journal, 358: j4008.
36. EUFIC (European Food Information Council). (2023a). The levels of evidence in nutrition research. Available at: **https://www.eufic.org/en/understanding-science/article/the-levels-of-evidence-in-nutrition-research** (Accessed 18th May 2024).
37. Hickson, M., Papoutsakis, C., Madden, A.M,. et al. (2024). Nature of the evidence base and approaches to guide nutrition interventions for individuals: a position paper from the Academy of Nutrition Sciences. British Journal of Nutrition, 131(10): 1754-1773.
38. ICRF (Imperial Clinical Research Facility). (2015). Glossary of research terms. Available at: **CRF-Glossary-of-research-terms.pdf (imperial.ac.uk)** (Accessed 19th July 2024).
39. EUFIC (European Food Information Council). (2017a). Difference between correlation and causation (infographic). Available at: **Difference Between Correlation and Causation (Infographic) | Eufic** (Accessed 19th July 2024).
40. WCRF/AICR (World Cancer Research Fund/American Institute for Cancer Research). (2018c). Diet, nutrition, physical activity and colorectal cancer: a global perspective. Available at: **https://www.wcrf.org/wp-content/uploads/2021/02/Summary-of-Third-Expert-Report-2018.pdf** (Accessed 6th June 2024).
41. Guyatt, G.H., Oxman, A.D., Vist, G.E. et al. (2008). GRADE Working Group. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. British Medical Journal 336(7650): 924-926.
42. Andrews, J., Guyatt, G., Oxman, A.D. et al. (2013a). GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. Journal of Clinical Epidemiology, 66(7): 719-725.

43. Andrews, J.C., Schűnemann, H.J., Oxman, A.D. et al. (2013b). GRADE guidelines: 15. Going from evidence to recommendation-determinants of a recommendation's direction and strength. Journal of Clinical Epidemiology, 66: 726-735.
44. BMJ Best Practice. (2024). A glossary of EBM terms. Available at: **https://bestpractice.bmj.com/info/us/toolkit/ebm-tools/a-glossary-of-ebm-terms/** (Accessed 19th July 2024).
45. Schwingshackl, L., Knüppel, S., Schwedhelm, C. et al. (2016). Perspective: NutriGrade: a scoring system to assess and judge the meta-evidence of randomized controlled trials and cohort studies in nutrition research. Advances in Nutrition. 7(6): 994-1004.
46. Shapiro, S. (2004). Looking to the 21st century: have we learned from our mistakes, or are we doomed to compound them? Pharmacoepidemiology and Drug Safety, 13: 257-265.
47. Aromataris, E., Fernandez, R., Godfrey, C.M. et al. (2015). Systematic reviews: methodological development, conduct and reporting of an umbrella review approach. International Journal of Evidence Based Healthcare, 13: 132–140.
48. EUFIC (European Food Information Council). (2023b). How strong is the scientific evidence? Available at: **https://www.eufic.org/en/understanding-science/article/hierarchy-of-science-evidence-infographic** (Accessed 18th May 2024).
49. COMA (Committee on Medical Aspects of Food and Nutrition Policy). (1998). Nutritional aspects of the development of cancer. Report of the Working Group on Diet and Cancer of the Committee on Medical Aspects of Food and Nutrition Policy. Reports on Health and Social Subjects (Lond). 48: i-xiv, 1-274.
50. EUFIC (European Food Information Council). (2023a). The levels of evidence in nutrition research. Available at: **https://www.eufic.org/en/understanding-science/article/the-levels-of-evidence-in-nutrition-research** (Accessed 18th May 2024).
51. MSF (Medecins Sans Frontierers). (2024). Noncommunicable diseases. Available at: **https://msf.org.uk/issues/non-communicable-diseases#:~:text=Risk%20factors%20include%20smoking%2C%20air,patients%20can%20control%20their%20symptoms** (Accessed 27th April 2024).
52. Public Health England. (2018). A quick guide to the Government's Healthy Eating Recommendations **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/742746/A_quick_guide_to_govt_healthy_eating_update.pdf** (Accessed 8th July 2023).
53. Food Systems Dashboard (2023) Available at: **https://www.foodsystemsdashboard.org/indicators/outcomes/nutritional-status/anemia-in-women-15-49-years/map** (Accessed 10th March 2024).
54. WCRF (World Cancer Research Fund). (2023a). Limit red meat and avoid processed meat. Available at: **https://www.wcrf.org/diet-activity-and-cancer/cancer-prevention-recommendations/limit-red-and-processed-meat/** (Accessed 1st Aug 2023).
55. WCRF/AICR (World Cancer Research Fund and American Institute for Cancer Research). (1997). Food, Nutrition and the Prevention of Cancer: A Global Perspective. American Institute for Cancer Research, Washington, DC.
56. IARC (International Agency for Research on Cancer). (2018). Red Meat and Processed Meat – IARC monographs on the evaluation of carcinogenic risks to humans. Lyon: International Agency for Research on Cancer/World Health Organization. Available at: **https://publications.iarc.fr/564** (Accessed 8th April 2023).
57. Key, T.J., Appleby, P.N., Spencer, E.A. et al. (2009a). Cancer incidence in British vegetarians. British Journal of Cancer, 101(1): 192–197.
58. Sanjoaquin, M.A., Appleby, P.N., Thorogood, M. et al. (2004). Nutrition, lifestyle and colorectal cancer incidence: a prospective investigation of 10998 vegetarians and non-vegetarians in the United Kingdom. British Journal of Cancer, 90(1): 118–121.
59. Key, T.J., Appleby, P.N., Spencer, E.A. et al. (2009b). Cancer incidence in vegetarians: results from the European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford). American Journal of Clinical Nutrition, 89(5): 1620S–1626S.

60. Henderson, L., Gregory, J., Swan, G. (2002). The National Diet and Nutrition Survey: adults aged 19 to 64 years. Volume 1: Types and quantities of foods consumed. London: The Stationery Office.
61. IARC (International Agency for Research on Cancer). (2015a). IARC Monographs evaluate consumption of red and processed meat. Released 26th October, 2015. Available at: **https://www.iarc.who.int/wp-content/uploads/2018/07/pr240_E.pdf** (Accessed 13th April 2023).
62. BLNZ (Beef and Lamb New Zealand). (2020). The role of red meat in health and sustainable New Zealand diets. Available at: **https://static1.squarespace.com/static/5afa23cc50a54ff627bbcea9/t/5fc810cc3e8bcb4f70ca7ec4/1606947105752/role+of+red+meat+report-web+version.pdf** (Accessed 19th July 2024)
63. IARC (International Agency for Research on Cancer). (2024). Cancer Today. Available at: **https://gco.iarc.fr/today/en/dataviz/tables?mode=cancer&populations=826&cancers=8&types=0&group_populations=1&key=total&sexes=0&age_end=14** (Accessed 21st April 2024). OR **Source: https://gco.iarc.fr/today/en/**
64. British Nutrition Foundation. (2023a). Exploring current consumption of red meat and nutrition contribution of red meat and dairy to UK diets, (Unpublished, June 2023) pp.1-12.
65. Food Standards Scotland. (2024). Modelling the impact of reductions in meat and dairy consumption on nutrient intakes and disease risk. Available at: **https://www.foodstandards.gov.scot/downloads/Summary_briefing_-_Modelling_the_impact_of_reductions_in_meat_and_dairy_.pdf** (Accessed 13th March 2024).
66. Climate Change Committee (CCC). (2020). The sixth carbon budget – the UK's path to net zero. December, 2020. London, Committee on Climate Change.
67. Santarelli, R.L., Pierre, F., Corpet, D.E. (2008). Processed meat and colorectal cancer: a review of epidemiologic and experimental evidence. Nutrition and Cancer, 60(2): 131-144.
68. Le, N.T., Michels, F.A., Song, M. et al. (2016). A prospective analysis of meat mutagens and colorectal cancer in the Nurses' Health Study and Health Professionals Follow-up Study. Environmental Health Perspectives, 124(10): 1529-1536.
69. Alisson-Silva, F., Kawanishi, K., Varki, A. (2016). Human risk of diseases associated with red meat intake: analysis of current theories and proposed role for metabolic incorporation of a non-human sialic acid. Molecular Aspects of Medicine, 51: 16-30.
70. Berjia, F.L, Poulsen, M., Nauta, M. (2014). Burden of diseases estimates associated to different red meat cooking practices. Food and Chemical Toxicology, 66: 237-244.
71. Baghurst, P. (2007) Colorectal cancer. Nutrition and Dietetics, 64 (Suppl 4): S173-S180.
72. Hughes, R., Cross, A.J., Pollock, J.R.A., Bingham, S. Dose-dependent effect of dietary meat on endogenous colonic N nitrosation. (2001) Carcinogenesis 22: 199–202.
73. Cross, A.J., Pollock, J.R.A., Bingham, S.A. Haem, not protein or inorganic iron, is responsible for endogenous intestinal N-nitrosation arising from red meat. Cancer Res 2003; 63:2358–60.
74. Le Leu, R.K., Winter, J.M., Christophersen, C.T. et al. (2015). Butyrylated starch intake can prevent red meat-induced O6-methyl-2-deoxyguanosine adducts in human rectal tissue: a randomised clinical trial. British Journal of Nutrition, 114(2): 220-230.
75. WCRF (World Cancer Research Fund). (2022b). Global Cancer Update Programme – Strategy and Plans (2022-2025). Available at: **https://www.wcrf.org/wp-content/uploads/2022/10/CUP-Global-Strategyweb.pdf** (Accessed April 24th 2024).
76. Pouzou, J.G. and Zagmutt, F.J. (2024a) Guidelines to restrict consumption of red meat to under 350g/wk based on colorectal cancer risk are not consistent with health evidence. Nutrition. 122: 112395.
77. British Nutrition Foundation Task Force. (2019). Cardiovascular Disease: diet, nutrition and emerging risk factors, Second Edition. Edited by Stanner, S and Coe, S. Chaired by Frayn, K. British Nutrition Foundation: London, John Wiley & Sons Ltd.
78. British Heart Foundation. (2024b). Atherosclerosis. Available at: **https://www.bhf.org.uk/informationsupport/conditions/atherosclerosis** (Accessed 12th June 2024).

79. Mozaffarian, D., Micha, R., Wallace, S. (2010). Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: a systematic review and meta-analysis of randomized controlled trials. PloS Medicine, 7(3): e1000252.
80. Department of Health and Social Care. (2023). Great Britain Nutrition and Health Claims Register. Available at: **https://www.gov.uk/government/publications/great-britain-nutrition-and-health-claims-nhc-register** (Accessed 23rd October 2023).
81. SACN (Scientific Advisory Committee on Nutrition). (2003). Salt and Health. Available at: **https://assets.publishing.service.gov.uk/media/5a74983de5274a44083b7ef6/SACN_Salt_and_Health_report.pdf** (Accessed 12th June 2024).
82. British Heart Foundation. (2024c). Healthy Living. Available at: **https://www.bhf.org.uk/informationsupport/publications/preventing-heart-disease** (Accessed 24th July 2024).
83. Abete, I., Romaguera, D., Vieira, A.R. et al. (2014). Association between total, processed, red and white meat consumption and all-cause, CVD and IHD mortality: a meta-analysis of cohort studies. British Journal of Nutrition, 112: 762–775.
84. Schwingshackl, L., Schwedhelm, C., Hoffmann, G. et al. (2017). Food groups and risk of hypertension: a systematic review and dose-response meta-analysis of prospective studies. Advances in Nutrition, 8: 793–803.
85. Kim, K., Hyeon, J., Lee, S.A. et al. (2017). Role of total, red, processed, and white meat consumption in stroke incidence and mortality: a systematic review and meta-analysis of prospective cohort studies. Journal of the American Heart Association, 6(9): e005983.
86. Bechthold, A., Boeing, H., Schwedhelm, C. et al. (2019). Food groups and risk of coronary heart disease, stroke and heart failure: a systematic review and dose-response meta-analysis of prospective studies. Critical Reviews in Food Science and Nutrition. 59: 1071–1090.
87. Zeraatkar, D., Ah Han, M., Guyatt, G.H. et al. (2019a). Red and processed meat consumption and risk for all-cause mortality and cardiometabolic outcomes: a systematic review and meta-analysis of cohort studies. Annals of Internal Medicine, 171: 703-710.
88. Mente, A., Dehghan, M., Rangarajan, S. et al. (2023). Diet, cardiovascular disease, and mortality in 80 countries. European Heart Journal, 44(28): 2560-2579.
89. Iqbal, R., Dehghan, M., Mente, A. et al. (2021) Associations of unprocessed and processed meat intake with mortality and cardiovascular disease in 21 countries [Prospective Urban Rural Epidemiology (PURE) Study]: a prospective cohort study. American Journal of Clinical Nutrition, 114(3): 1049-1058.
90. Canada Beef. (2024). PURE Study finds unprocessed red meat is not associated with CVD. Available at: https://thinkbeef.ca/wp-content/uploads/2021/06/6.PURE-Unprocessed-Red-Meat_2.pdf (Accessed 5th May 2024).
91. Jakobsen, M.U., Bysted, A., Mejborn, H. et al. (2021). Intake of unprocessed and processed meat and the association with cardiovascular disease: an overview of systematic reviews. Nutrients, 13(10): 3303.
92. Grosso, G., La Vignera, S., Condorelli, R.A. et al. (2022). Total, red and processed meat consumption and human health: an umbrella review of observational studies. International Journal of Food Sciences and Nutrition, 73(6): 726–737.
93. Hill, E.R., O'Connor, L.E., Wang, Y. et al. (2024). Red and processed meat intakes and cardiovascular disease and type 2 diabetes mellitus: an umbrella systematic review and assessment of causal relations using Bradford Hill's criteria. 138omposit Reviews in Food Science and Nutrition, 64(9): 2423-2440.
94. Hill, A. B. (1965). The environment and disease: association or causation? Proceedings of the Royal Society of Medicine, 58(5): 295–300.
95. O'Connor, L.E., Kim, J.E., Campbell, W.W. (2017). Total red meat intake of ≥0.5 servings/d does not negatively influence cardiovascular disease risk factors: a systemically searched meta-analysis of randomized controlled trials. American Journal of Clinical Nutrition, 105(1): 57-69.

96. Zeraatkar, D., Johnston, B.C., Bartoszko, J. et al. (2019b). Effect of lower versus higher red meat intake on cardiometabolic and cancer outcomes: a systematic review of randomized trials. Annals of Internal Medicine, 171: 721-731.
97. Assaf, A.R., Beresford, S.A., Risica, P.M., et al. (2016). Low-fat dietary pattern intervention and health-related quality of life: the Women's Health Initiative randomized controlled dietary modification trial. Journal of the Academy of Nutrition and Dietetics, 116: 259-271.
98. Guasch-Ferré, M., Satija, A., Blondin, S.A. et al. (2019). Meta-analysis of randomized controlled trials of red meat consumption in comparison with various comparison diets on cardiovascular risk factors Circulation, 139: 1828–1845.
99. Diabetes UK. (2024b). Diabetes: The basics. Available at: **https://www.diabetes.org.uk/diabetes-the-basics** (Accessed 17th June 2024).
100. Diabetes UK. (2018). Evidence-based nutrition for the prevention and management of diabetes. Available at**: https://diabetes-resources-production.s3.eu-west-1.amazonaws.com/resources-s3/2018-03/1373_Nutrition%20guidelines_0.pdf** (Accessed 25th May 2024).
101. Dyson, P.A., Twenefour, D., Breen, C. et al. (2018). Diabetes UK evidence-based nutrition guidelines for the prevention and management of diabetes. Diabetic Medicine, 35(5): 541-547.
102. van Nielen, M., Feskens, E.J., Mensink, M. (2014). Dietary protein intake and incidence of type 2 diabetes in Europe: the EPIC-InterAct Case-Cohort Study. Diabetes Care, 37(7): 1854-62.
103. Pan, A., Sun, Q., Bernstein, A.M. et al. (2011). Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. The American Journal of Clinical Nutrition, 94(4): 1088-1096.
104. InterAct Consortium. (2013). Association between dietary meat consumption and incident type 2 diabetes: The EPIC-InterAct study. Diabetologia, 56: 47–59.
105. Paulweber, B., Valensi, P., Lindstrom, J. et al. (2010). A European evidence-based guideline for the prevention of type 2 diabetes. In IMAGE Guidelines. Hormone and Metabolic Research, 42: S1-S64.
106. Zhang, R., Fu, J., Moore, J.B. et al. (2021). Processed and unprocessed red meat consumption and risk for type 2 diabetes mellitus: an updated meta-analysis of cohort studies. International Journal of Environmental Research and Public Health, 18(20): 10788.
107. Neuenschwander, M., Ballon, A., Weber, S. et al. (2019). Role of diet in type 2 diabetes incidence: umbrella review of meta-analyses of prospective observational studies. British Medical Journal, 366: l2368.
108. O'Connor, L.E., Kim, J.E., Clark, C.M. et al. (2021). Effects of total red meat intake on glycemic control and inflammatory biomarkers: a meta-analysis of randomized controlled trials. Advances in Nutrition, 12(1): 115-127.
109. Kim, Y., Keogh, J., Clifton, P. (2015). A review of potential metabolic etiologies of the observed association between red meat consumption and development of type 2 diabetes mellitus. Metabolism, 64(7): 768–779.
110. Kuipers, R.S., Pruimboom, L. (2016). Short comment on "A review of potential metabolic etiologies of the observed association between red meat consumption and development of type 2 diabetes mellitus" by Yoona Kim, Jennifer Keogh, Peter Clifton. Metabolism 65(1): e3–4.
111. Sanders, L.M., Wilcox, M.L., Maki, K.C. (2023). Red meat consumption and risk factors for type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. European Journal of Clinical Nutrition, 77(2): 156-165.
112. Stanton, A.V., Leroy, F., Elliott, C. et al. (2022). 36-fold higher estimate of deaths attributable to red meat intake in GBD 2019: is this reliable? The Lancet, 399(10332): e23-e26.
113. Gordon-Dseagu, V.L.Z., Wiseman, M.J., Allen, K. et al. (2022). Troubling assumptions behind GBD 2019 on health risks of red meat. The Lancet, 400(10350): 427-428.
114. Johnston, B.C., Zeraatkar, D., Han, M.A. et al. (2019). Unprocessed red meat and processed meat consumption: dietary guideline recommendations from the Nutritional Recommendations (NutriRECS) Consortium. Annals of Internal Medicine, 171(10): 756-764.
115. Lescinsky, H., Afshin, A., Ashbaugh, C. et al. (2022). Health effects associated with consumption of unprocessed red meat: a Burden of Proof study. Nature Medicine, 28: 2075–2082.

116. Gakidou, E., Afshin, A., Alemu, A. et al. (2017). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet, 390(10100): 1345 – 1422.
117. Murray, C.J.L. GBD Risk Factors Collaborators. (2022). 36-fold higher estimate of deaths attributable to red meat intake in GBD 2019: is this reliable? – Author's reply. The Lancet, 399(10332): e27-e28.
118. Brauer, M., Roth, G.A., Aravkin, W.Y. et al. (2024). Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. The Lancet, 403(10440): 2162 – 2203.
119. GBD 2019 Risk Factors Collaborators. (2019). Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet, 396(10258): 1223-1249.
120. Stanton, A.V. (2024). Animal and plant source foods and human health – reflections on "too little" and "too much". Invited Lecture at the Nutrition Society Congress 2024, Belfast, UK, July 2024.
121. Defra (Department for Environment, Food and Rural Affairs). (2020). National Food Strategy for England. Available at: **https://www.gov.uk/government/publications/national-food-strategy-for-england** (Accessed 4th May 2024).
122. Willett, W., Rockström, J., Rockström, J. et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet Commissions. 393(10170): 447-492.
123. Zheng, P., Afshin, A., Biryukov, S. et al. (2022). The Burden of Proof studies: assessing the evidence of risk. Nature Medicine, 28(10): 2038-2044.
124. Pouzou, J.G. and Zagmutt, F.J. (2024b). Observational dose-response meta-analysis methods may bias risk estimates at low consumption levels: the case of meat and colorectal cancer. Advances in Nutrition, 15(5): 100214.
125. Shaw, P.A., Deffner, V., Keogh, R.H. et al. (2018). Epidemiologic analyses with error-prone exposures: review of current practice and recommendations. Annals of Epidemiology, 28(11): 821-828.
126. Cainzos-Achirica, M., Bilal, U., Kapoor, K. et al. (2018). Methodological issues in nutritional epidemiology research – sorting through the confusion. Current Cardiovascular Risk Reports. 12(4).
127. Zeraatkar, D., Cheung, K., Milio, K. et al. (2019c). Methods for the selection of covariates in nutritional epidemiology studies: a meta-epidemiological review. Current Developments in Nutrition, 3(10): nzz104.
128. Crippa, A., Discacciati, A., Bottai, M. et al. (2019). One-stage dose-response meta-analysis for aggregated data. Statistical Methods in Medical Research, 28(5): 1579-1596.
129. Leroy, F., Heinrich, F., Lee, M.R.F. et al. (2023). Meat matters: making the case for a valuable food in a hostile environment. Italian Journal of Animal Science, 22(1): 885-897.
130. Boffetta, P., McLaughlin, J.K., La Vecchia, C. et al. (2008). False-positive results in cancer epidemiology: a plea for epistemological modesty. Journal of the National Cancer Institute, 100(14): 988-995.
131. Solyakov, A. and Skog, K. (2002). Screening for heterocyclic amines in chicken cooked in various ways. Food and Chemical Toxicology, 40: 1205-1211.
132. Wretling, S., Eriksson, A., Eskhult, G. et al. (2010). Polycyclic aromatic hydrocarbons (PAHs) in Swedish smoked meat and fish. Journal of Food Composition and Analysis, 23: 264-672.
133. Sinha, R., Peters, U., Cross, A.J. et al. (2005). Meat, meat cooking methods and preservation, and risk for colorectal adenoma. Cancer Research, 65(17): 8034-8041.
134. Geiker, N.R.W., Bertram, H.C., Mejborn, H. et al. (2021). Meat and human health: current knowledge and research gaps. Foods, 10(7): 1556.

5. Sustainability of UK red meat

Introduction

Farmers provide one of life's most critical necessities – food – but they do more than just grow food; they provide a wealth of critical environmental services that will become increasingly important in the fight against climate change.

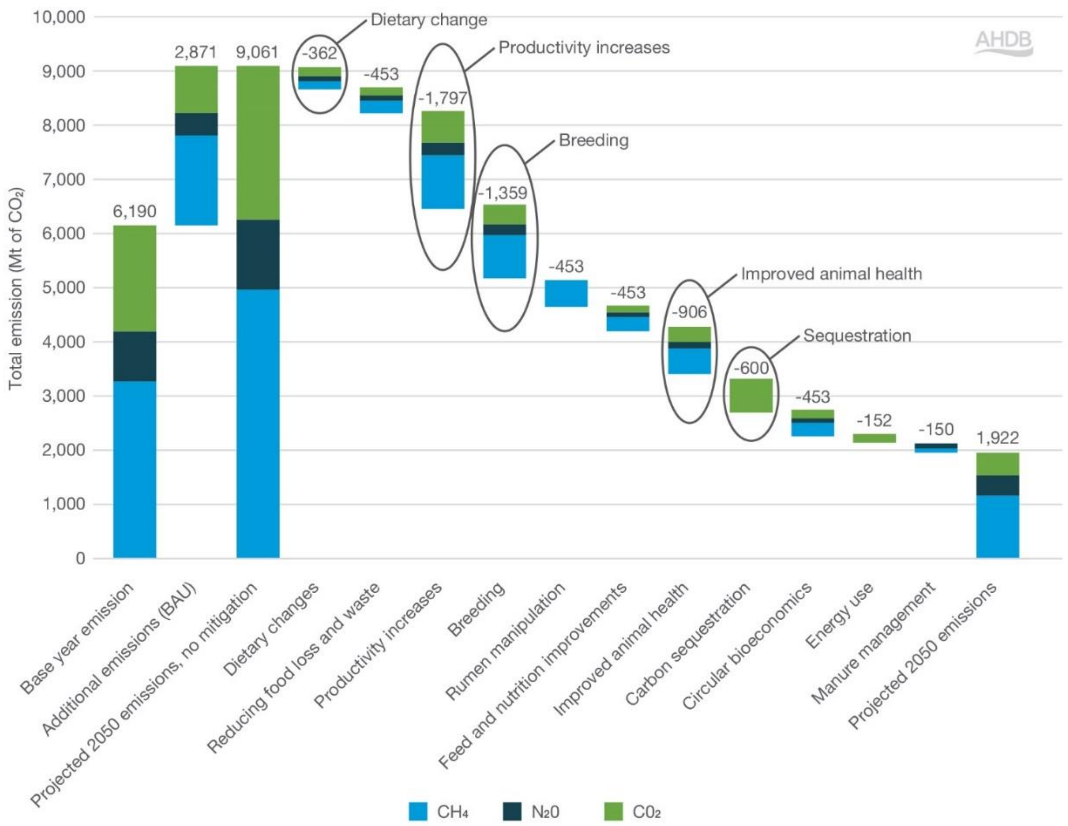
This includes being custodians of 70% of the UK's land[1], helping to manage water quality and flow, adapting to our changing climate, protecting and promoting soil health and productivity, enhancing biodiversity and maintaining, and adding to, the millions of tonnes of carbon stocks locked up in our soils and biomass within the natural landscape. In addition, livestock agriculture plays an important role in the economy, with the beef, sheep and pig sectors contributing value of £6.2 billion to the UK economy in 2021.[2]

This relationship and influence on the natural world present both a unique challenge and opportunity for agriculture, as while the UK legislation of reaching net zero by 2050 cements the need to dramatically reduce greenhouse gas emissions, it is also widely recognised that environmental sustainability is about more than reducing emissions alone. We must also make better use of natural resources, reduce waste, support nature recovery and, critically, remove more carbon from the atmosphere and store in our soils, trees and other natural biomass. Agriculture is unique in that it has great influence on all these actions, especially the latter.

To achieve a sustainable planet, the world does not necessarily need to eat less meat and dairy products. This is because livestock production can be genuinely circular and self-sustaining. In parts of the world with well-developed livestock industries, a focus on efficiency will maintain production with a lower number of animals, allowing the growing economies in Africa and Asia to develop with a re-balance of emissions driven by livestock numbers. In essence the reduction in emissions in the developed nations will in part offset the rise in emissions in Africa and Asia as these economies develop their livestock enterprises.

Net zero is where GHG emissions are balanced by activities that remove the same amount from the atmosphere – it is not about zero emissions. Even if consumption of livestock products increased by 21% between 2020 and 2050 as suggested by the Food and Agriculture Organization of the UN (FAO) in their *Pathway to Lower Emissions* report[3] (Figure 1), that can still be done while remaining within the 1.5°C temperature change limit with a small impact of global diet change, focusing on over consumption, particularly in developed nations. The FAO points to productivity increases, genetics and improved animal health as the most critical for delivering overall lower livestock emissions. That can be achieved by choosing livestock products that have been sustainably produced from the most environmentally better-suited regions of the world, such as the UK.

Figure 1. Pathway to lower livestock emissions



Source: FAO 2023

Consumers make their food and dietary choices based on a variety of factors, but the impact production of that food has had on the environment is becoming more important in their decision-making process. Unfortunately, the data and scientific evidence to help them make better informed decisions has not kept up with their demand. Consumers are faced with a myriad of messages, often compiled in a way to paint a particular picture or to get a specific point across. However, the messaging fails to show the true complexity of the system. For example, by:

1. Using global or regional averaged data to reflect a local product's footprint.
2. Comparing foods across different food categories that have no comparable nutritional value.
3. Focusing in on one environmental metric such as carbon while ignoring others such as biodiversity.
4. Focusing on just gross emissions and ignoring the benefits of carbon sequestration and removals, i.e. net emissions.
5. Representing all greenhouse gases as carbon dioxide equivalents (CO_{2e}) despite them acting very differently in the atmosphere. This particularly disadvantages industries that emit greenhouse gases other than CO_2 such as agriculture, which predominately emits methane and nitrous oxide.
6. Citing only one report while ignoring others that set out the counter argument.

Here we look at the evidence as it currently stands while highlighting the gaps and where decisions should be taken carefully. AHDB is currently working to help fill some of those gaps with an environmental baselining pilot of 170 farms across Great Britain.

What are we already doing?

Summary points

- UK farmers are already focused on producing nutritious food alongside reducing the environmental impact
- Agriculture was responsible for 12% of UK emissions in 2022 according to the UK GHG National Inventory; however, emissions for agriculture are more nuanced as sequestration and renewable energy generated from agriculture are accounted for in other parts of the inventory. The National Inventory equates all GHGs into carbon dioxide equivalents, whereas the majority of agriculture's emissions come from methane
- The agriculture sector is already embracing practices and technology to aid the reduction of methane emissions with awareness of the Global Methane Pledge and the FAO's roadmap to zero hunger
- Methane is currently calculated using the GWP100 metric, which calculates methane's warming potential over a period of 100 years, whereas emerging science indicates that this is inaccurate, and that given it is a short-lived gas, it breaks down much quicker, between 7 and 12 years, meaning that carbon emissions associated with agriculture are greatly reduced under the alternative metric, GWP*
- Carbon emissions for red meat are often quoted using global averages, whereas the predominant systems adopted in the UK cannot be compared to other global systems, with global averages being higher than that of the UK
- Agriculture is a source of both carbon emissions and carbon sequestration, and yet they are accounted for separately; it is critical that farms are accounted for using their net carbon positions – accounting for both their carbon emissions but also the carbon sequestration and storage that they provide

The livestock industry has focused on optimising resources within current systems, such as feed, and improving productivity for a given level of input which will reduce emissions intensity (emissions per unit of output). This is a critical responsibility for farmers and is a win-win as it will reduce costs, improve profitability and reduce the impact on the environment.

Since 1990, there has been a 21% and 26% decline in UK cattle and sheep numbers, respectively, which is principally due to continual changes to the Common Agricultural Policy until the mid-2000s. More recently, the numbers showed a decrease between 2017 and 2020[1], but stayed the same in 2021, with 9.6 million cattle and 33 million sheep.[4] From 1990 to 2020, there has been a decrease in the emissions intensity from both cattle and pigs, i.e. emissions per unit of meat (CO_2e per kg meat). This was due to both an overall decline in animal emissions and an increase in meat yield. However, there are further opportunities for the sheep sector nationally, with emissions intensity remaining relatively static.2

Even among these trends, in 2022, the UK met 87% of its supply needs of beef and veal with home production. With pork production, there is a slightly greater supply gap, with UK production comprising 69% of supply needs. However, mutton and lamb production exceeded net supply needs by 6.6%.[5]

The Committee on Climate Change (CCC) has recommended a 64% reduction in GHG emissions between 2018 and 2050 from the agriculture, land use and forestry sectors, and a 29% reduction target by 2035 (relative to 2021).[6] However, we should be careful with the interpretation of the CCC recommendations, given the complexity of where the breadth of farming activities sits across the GHG National Inventory's different silos and the level of importance that the CCC places on that National Inventory (see below section on carbon footprints of UK production).

Progress in agriculture has been demonstrated via the 2023 Defra Farm Practices Survey, which showed that 62% of farms consider GHGs to be fairly/very important, an increase from the 2019 figure of 55%. The main motivations were those that consider it good business practice (83%) and those that had concern for the environment (73%).[7]

The Global Methane Pledge agreed at COP26 in 2021 entails a reduction target of at least 30% of global methane emissions from 2020 levels collectively across all sources, including agriculture (e.g. from enteric fermentation) by 2030.[8] The UK is one of 155 participating countries. Subsequently, at COP28, the FAO set milestones in its roadmap for zero hunger that included a target to reduce global methane emissions from the global livestock sector by 25% by 2030 compared with 2020 while increasing total factor productivity for livestock by 1.7% per year by 2050. This is in the context of a predicted increase in overall global meat consumption and greater production efficiencies.[9]

As part of the UK government's net zero strategy, there is an ambition for 75% of farmers in England to be engaged in low-carbon practices by 2030, rising to 85% by 2035. Policy drivers here include the new sustainability and agri-environmental land management schemes in all nations of the UK.[10]

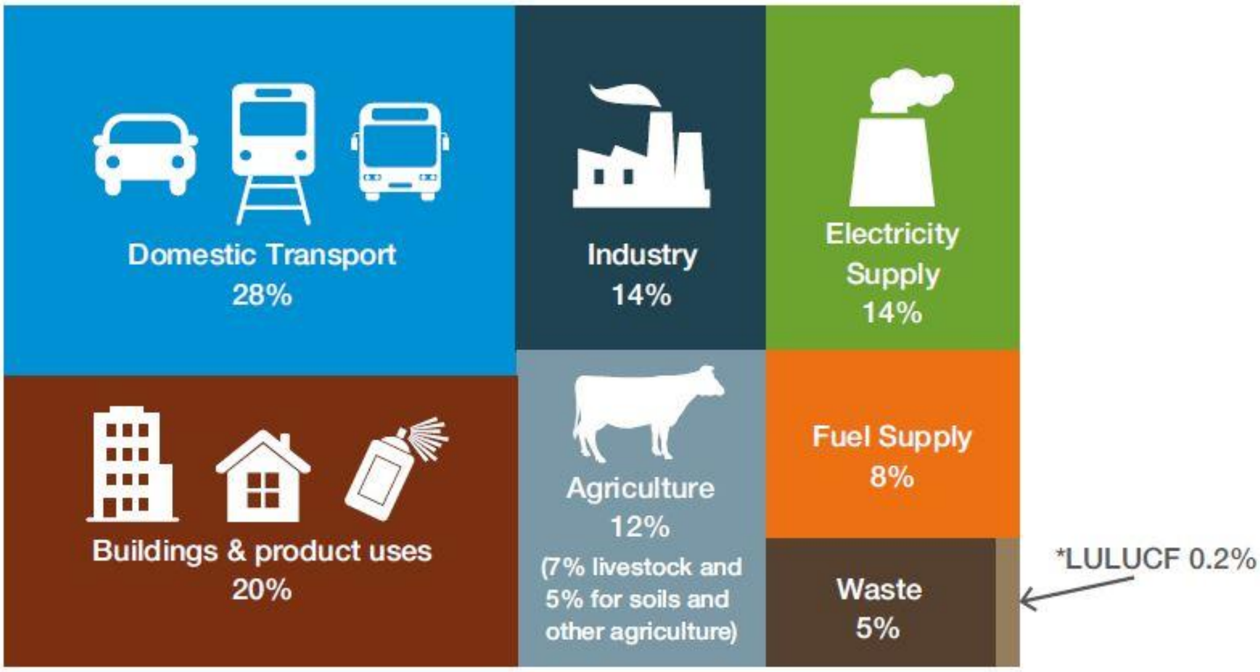
Accounting for GHGs of UK production

GHG emissions in the UK are reported through the GHG National Inventory, which suggests UK agriculture was responsible for 12% of total GHG emissions in 2022, with approximately 7% of the total emissions resulting from livestock (Figure 2).[11] Four sectors were reported as greater emitters: i) domestic transport at 28%, ii) buildings and product at 20%, iii) industry at 14% and iv) electricity supply at 14%. In comparison to the UK, global livestock emissions represent 14.5% of all anthropogenic GHG emissions (7.1 Gt CO_2e per year).[12]

However, care should be taken when considering farming purely based on the GHG National Inventory. While the inventory is useful for tracking the country's delivery against targets, there are limitations when looking at agriculture. The National Inventory reports emissions based on several silos and at a CO_{2e} level. Farming businesses do not fit neatly in just one of the silos and emit predominately non-CO_2 GHGs, unlike the other sectors.

The agriculture silo only looks at the GHG emissions related to the growing or rearing of food. It does not include changes to agricultural land use that might increase carbon sequestration, such as planting more trees – these are instead captured in the figures for land use, land use change and forestry (LULUCF). Similarly, on-farm energy generation, such as solar panels, wind turbines or anaerobic digestion, is captured within the energy silo. This means that agriculture's gross emissions do not reflect the net impact of sequestration, nor its direct influence on renewable energy generation.

Figure 2. UK greenhouse gas emissions by sector source11



Key: *LULUCF = Land use, land-use change and forestry. Source. DESNZ, 2024[11].

The main GHGs from agriculture are methane and nitrous oxide, and these comprise 58% and 26% of agricultural GHG emissions, respectively (based on GWP100 and CO_2e).11 The majority of agricultural methane in livestock agriculture arises from enteric fermentation, the by-product of a biological process of ruminants during digestion. Nitrous oxide predominately comes from the application of manufactured fertilisers and manures to soils, either directly or indirectly.

All figures quoted in the GHG National Inventory use GWP100[13], the most used global warming potential (GWP) value. It is used to compare different GHGs over 100 years and is expressed as carbon dioxide (CO_2) equivalents or CO_2e focusing on carbon emissions rather than warming per se.

GWP*13 is a new measure for calculating the impact of emissions of methane on the climate, taking account of the short-lived nature of methane and the rate of new emissions, focusing on the impact of the emissions on the warming effect.[14] The application of GWP*[15] is currently nascent and evolving, but it better represents methane emissions from agriculture on global warming. Enteric fermentation-evolved methane is part of a biogenic carbon cycle, and when the methane is decomposed over a period of 7 to 12 years15, the resulting carbon dioxide is returned to the natural carbon cycle. This is different to other anthropogenic methane sources such as mining and natural gas leaks which are not part of a natural carbon cycle, a point which has recently been recognised by the IPCC emission factors for biogenic and thermogenic methane.

In July 2023, 10 internationally recognised scientists, from eight of the UK's leading science institutes, published an academic letter in support of using GWP* as part of assessing climate impacts.[16] The study highlights the necessity of reporting the climate impacts of food under multiple measures, over multiple time horizons and on individual GHGs, as well as collectively in CO_2 equivalents. This complexity is required to allow decision makers to be fully informed, with more consideration to be given to broader sustainability issues, e.g. human health, agricultural resilience, nutritional complexities and global food security. The authors acknowledge that GWP* is a more accurate way of measuring the warming impact of methane and call for dual reporting, along with GWP100 at a national level, as a carbon auditing tool, on which debate continues.[17]

Global averages

When red meat carbon footprints are debated, it is often global footprints that are cited, and the footprints for a single product are considered to be homogenous. It is important to acknowledge the variation between the systems in different countries, e.g. genetics and health, grazing and housing, as well as local factors such as terrain, availability of resources (water, by-product feed) and climate. Thus, global averages are rarely representative of a UK product, and obtaining further life cycle assessments (LCA) based on primary local data to **IPCC tier 3**[18] standards in the future is imperative.

Table 1 shows the product carbon footprints for red meat products (emissions intensity), encompassing global and UK footprints, as **gross emissions only**. Some comparisons are given in GWP* – these are expressed as CO_2we (carbon dioxide warming equivalents). The carbon footprint calculations do not include carbon sequestration or any other farm intervention to reduce emissions or capture carbon through net primary production or green energy (see above with respect to silos of agriculture).

Table 1. Red meat gross emissions per unit of output GWP 100 (kg CO_2e/kg product (unless stated)) and GWP* (kg CO_2we/kg product) excluding carbon sequestration

Enterprise	Beef (dairy herd)	Beef (beef herd)	Lamb and mutton	Pork
UK: Agrecalc (2024)[b] kg CO_2e/kg (GWP100, CO2e)	22.1	32.4	29.5	4.96
UK: Agrecalc (2023)[c] kg CO_2e/kg (GWP*, CO_2we)	9.06	9.75	-0.13	Not available
UK: Poore and Nemecek (2018)[a] kg CO_2e/kg (GWP100, CO2e)	25.9	48.4	37.4	11.48
Global: Poore and Nemecek (2018)[a] CO_2e/100g protein[d] (GWP100, CO_2e)	16.9	49.9	19.9	7.6
Global: Poore and Nemecek (2018)[a] kg CO_2e/kg (GWP100, CO_2e)	33.3	99.5	39.7	12.3

Notes: [a] From Poore and Nemecek[19]; a study published in Science in 2018. NB: there are a limited number of data points in each respective data set and is more limited in the country data set. The system boundary of the P&N study is cradle-to-retail. Figures per 100 g protein given in brackets.

[c] Agrecalc[20], carbon and efficiency calculator; data from farms with applicable enterprises 2018–2022, AR4 GWP. Mean gross emissions only, emissions to farmgate as CO_2e/kg deadweight (dwt) and CO_2we/kg deadweight (dwt). The GWP* calculation is based on national emissions trends.

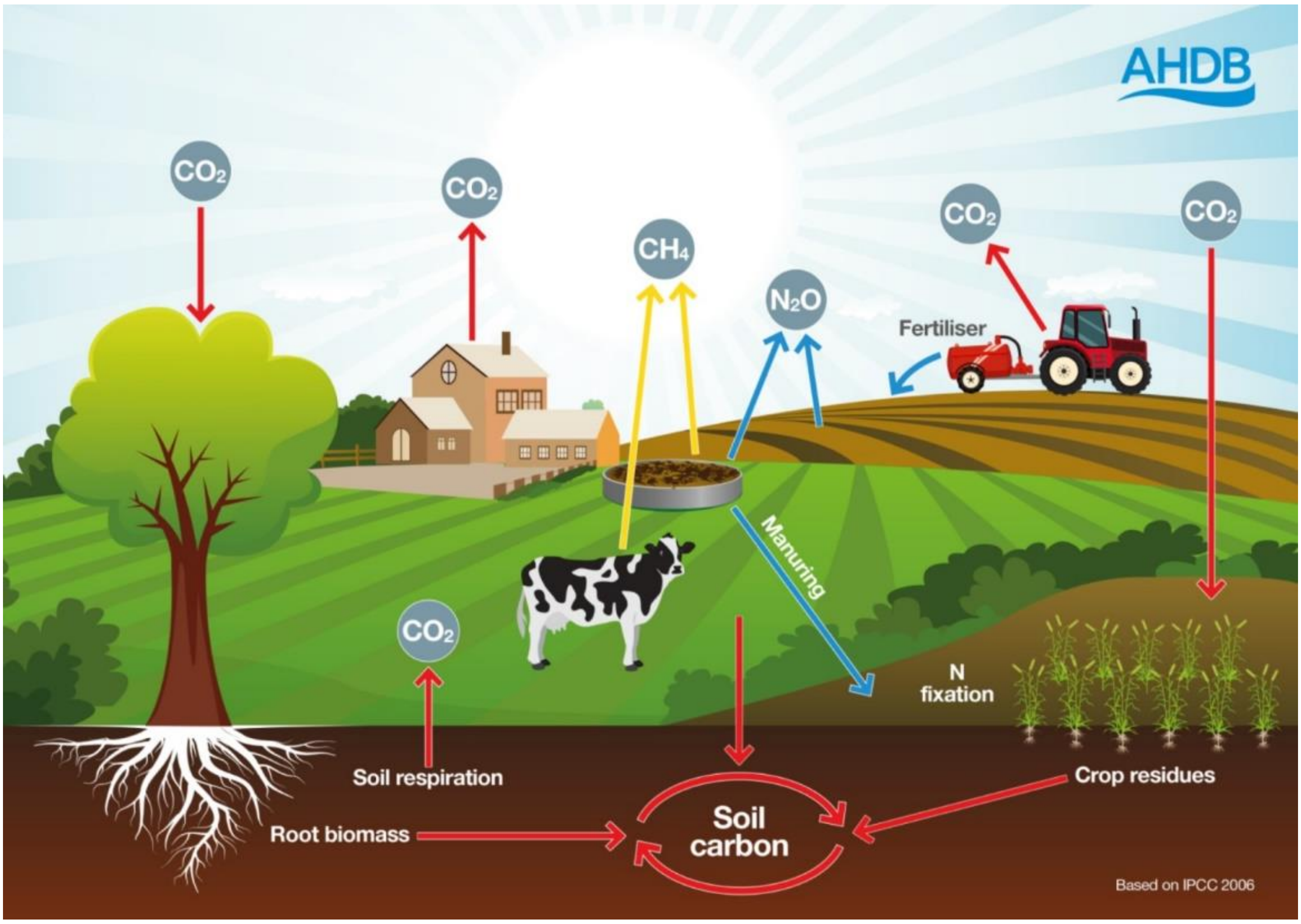
[d] Not digestible indispensable amino acid score (DIAAS) corrected. DIAAS is a measure of protein quality in relation to its composition and digestibility – all proteins are different where a 50% score would require twice as much protein as a 100% protein source. Animal source proteins have higher DIAAS scores than plant protein sources.[21]

Overall, the land-use and farm-production emissions combined account for more than 80% of the product footprint for most foods.19 While the GHG or carbon footprint provide an indicator for potential climate change impacts through global warming potential, they should not be viewed in isolation but considered alongside other environmental pressures and impacts to the ecosystem, such as effects on water quality and biodiversity.

Net zero, not gross zero

The journey to net zero began in Paris in 2015, where 196 parties of the UN Climate Change Convention agreed under section 1a to limit global warming to ideally 1.5°C (section 1b stating this needs to be done without reducing the planet's ability to produce food). To do this, emissions will need to reach net zero by 2050. A decade on, and still the meaning of net zero is largely misunderstood. Net zero is defined in science and law and does not mean zero emissions – zero would mean no animals and no humans on Earth. Net zero is defined as where any GHG emissions are reduced as much as possible, with any remaining emissions balanced by activities that remove the same amount from the atmosphere (Figure 3).[22]

Figure 3. Determining carbon balance (net zero GHG emissions) by analysing how agriculture interacts with the whole environment, including carbon removal and nature recovery



Source: AHDB

Despite this, emissions from agriculture are reported in gross emissions. Globally, agriculture accounts for around 12%[23] of direct emissions and a similar figure of 12%[11] of UK emissions. Critically missing from these figures is the other side of the equation – the removal and storage of carbon from the atmosphere. Agriculture covers almost half of the Earth's habitable land[24], a patchwork of habitats and landscapes that, through the process of photosynthesis, the absorption of carbon dioxide and releasing of oxygen by plants, removes carbon from the atmosphere. This is known as carbon flux, and when this carbon is removed for an indefinite period, this is defined as sequestration[25]. However, under current reporting rules of the National GHG Inventories, carbon negative-flux or sequestration is not accredited against the farming sector, instead reported as a separate sector called land use, land-use change and forestry (LULUCF). This is the same for carbon removal activities such as woodland creation, soil improvement or green energy production on farm.

Similarly, carbon footprint calculations for food products largely also only factor in GHG emissions, not carbon sequestration, nor carbon removals. When sequestration and carbon flux removal rates are declared, they are crude international averages rather than actual relevant farm-level data.

Additionally, most farms are a complex integrated system, producing a diverse range of foods and other products and services. Reporting an individual food footprint often fails to acknowledge the considerable benefits from an integrated system, taking the simplest route and declaring the emissions of that food product and not the wider carbon impact and benefits of the whole farm business, with allocation usually associated with economic value.

To address this simplistic approach, and for UK agriculture to help deliver net zero by 2050, measuring and reporting on the balance of both GHG emissions and carbon removals as a singular net-carbon position is critical. This insight and knowledge will empower farmers to make the right decisions for their landscapes and farming systems, as well as receive due recognition and reward. However, this all starts with a baseline.

Within agriculture, delivering net zero aligns to agriculture's unique position and ability to be circular relying on the balancing of the following:

- Understanding where GHG emissions come from **and** how to reduce them
- Understanding where carbon stocks are in the landscape **and** how to increase them
- Displacing fossil fuel emissions by generating renewable energy **and** minimising methane emissions by optimising waste management

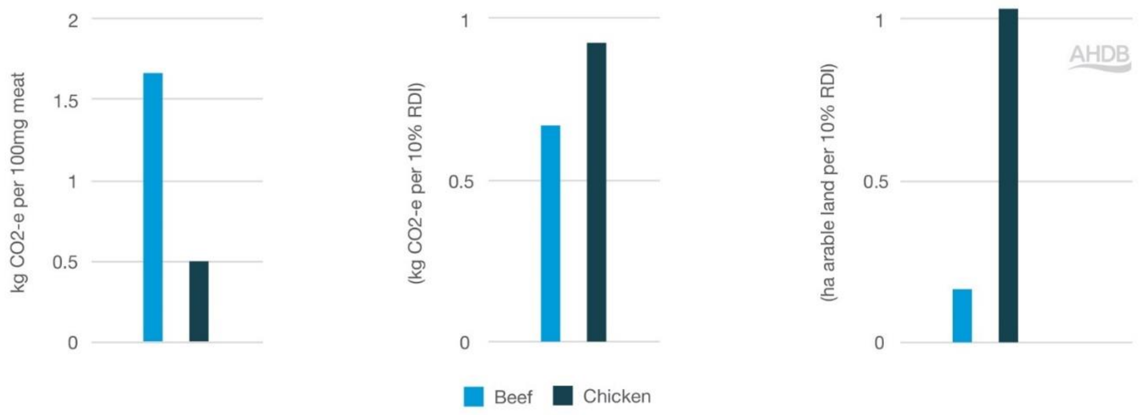
To understand this position, a nationwide measurement, or baseline, must be obtained, offering both transparency and integrity to the entire journey. To demonstrate accurate change, whether positive or negative, the baseline measurement must be repeated every five years, as carbon stocks in the landscape are not permanent and can both be increased and lost. AHDB are currently undertaking a pilot scheme on 170 farms across Great Britain to take such baselining measurements.

Nutrient density and carbon footprint

As we have done earlier in this report, the carbon footprints of food products are often compared on GHG emissions per unit mass. Although they can be useful for comparisons between countries, or between similar products, studies have concluded that the nutritional value of a food item should be used to define its environmental impact to allow fair comparisons across different food groups such as protein.[21,26,27]

Through the lens of the recommended daily intake (RDI) of 12 essential nutrients, including omega-3 fatty acids (DHA), vitamin B12 and protein, grass-fed beef has a lower carbon footprint than free-range chicken and a lesser land footprint (Figure 4).27,[28]

Figure 4. Carbon footprint of grass-fed beef and free-range chicken per weight of meat (left) and per contribution to recommended daily intake of 12 essential nutrients (centre) and area of arable land use per nutrient density provision (right) 28



Source: Lee et al., 2021[27]

Integrating the nutritional value in environmental footprint comparisons as a functional unit provides better insight into economic and environmental trade-offs fundamental to each production system and thus the on-farm mitigation practices that should be encouraged. Calculations could go one step further by considering the bioavailability of key nutrients such as DIAAS, iron and zinc, highlighting at a micro level the nutritional versus environmental impact of the diet. This would aid consumer awareness of differences in food quality in relation to climate impacts.

Livestock

Summary points

- UK farms have some of the highest levels of animal health and welfare in the world, much of it being underpinned in legislation
- There is a distinct correlation between maintaining high animal health and welfare and the reduction in carbon emissions due to the impact of productivity, with high animal health being a key driver in sustainable livestock systems
- Genetics play an important part in underpinning the sustainable production of animal-derived protein; genetic developments have accelerated over recent years, enabling farmers to reduce their gross GHG emissions
- Beef cattle and sheep in the UK are predominantly fed grass, often utilising marginal land that would be unsuitable for growing other crops

- Grazed ruminants help to create and manage a complex mosaic of habitats, particularly in upland areas
- UK pig diets are aligned with the circular economy, with a high proportion of their diet coming from by- and co-products

UK farmers' passion and commitment to doing the best for their animals results in the production of nutritious meat which millions of people enjoy every day as part of a balanced diet. High standards of animal health and welfare underpin British livestock farming, ensuring livestock are provided with comfort, feed, space and the other essentials to allow them to thrive. Consistently treating animals well is not just the right thing to do, it also makes good business sense, as healthy, well-cared-for animals lead to reduced need for antibiotic usage, increased efficiency and lower environmental impacts.

Britain has some of the highest legislative animal welfare standards in the world, which are further supplemented by independent quality audits by a variety of assurance schemes (e.g. Red Tractor, RSPCA Assured, Farm Assured Welsh Livestock Beef and Lamb Scheme, Quality Meat Scotland Cattle and Sheep Assurance Scheme, BMPA Quality Assured Pork) so that people can be confident in British meat products. Participation in these assurance schemes requires farmers to have a documented animal health plan and adhere to animal welfare principles above the minimum legal requirement. The FAO highlights animal health as a key component to delivering sustainable livestock products.[29]

The way in which farmers care for their herds and flocks is influenced by the farm's geographical location, the climate and surrounding landscape. On-farm practices are monitored by a number of professionals, such as vets, nutritionists and advisers.

Genetic developments

Breeding is another critical element of the FAO's pathway to lower livestock emissions, and the UK is at the forefront of genetic improvement for livestock farmers, particularly when it comes to dairy developments.

Genetic improvement and breeding practices in cattle and sheep can contribute to reducing livestock emissions via herd and flock productivity and efficiency. Estimated breeding values (EBV) are used to value the genetic worth of animals using desirable traits such as meat production. In 2023, when breeding beef cattle, 32% of livestock holdings used bulls with a high EBV at least some of the time. In sheep, 36% used rams with a high EBV at least some of the time when breeding lambs.[30]

Every year, the economic value of the genetic gain achieved by dairy farmers accumulates. In addition, a reduced level of greenhouse gases is achieved and is estimated to have been about 0.8% per year because of genetic improvement. AHDB's EnviroCow[31] is a further genetics tool to help farmers breed dairy cows for their environmental credentials. It incorporates cow lifespan, milk production, fertility and the ability to convert feed, all of which – since its introduction – have been re-estimated to be now just over 1% per year. Genetic improvement is both permanent and accumulates over generation; the impact over a 20-year horizon is substantial.

In beef, an AHDB report[32] found that if the historic rate of genetic gain continues, it will deliver annualised economic benefits over the next 20 years as well as environmental benefits, leading to a reduction in gross emissions of 0.08% per year and 0.13% reduction in emissions intensity per year, totalling 1.6% and 2.6% over the 20 years, respectively. In the same study, it is anticipated that in sheep, a reduction in gross emissions of 0.1% per year and 0.23% reduction in emissions intensity per year will be achieved by genetic improvement, totalling 2% and 4.6%, respectively. However, the industry is accelerating progress in this area, driving rapid genetic improvements, with AHDB planning to expand its portfolio of genetic tools across sectors.

Beef

Cattle in the UK are primarily fed on grass. They are ruminants, which convert plant material that is indigestible by humans to nutrient-dense food and readily available micronutrients and return carbon to the soil through their manures.

In fact, grass-derived feed amounts to 91% of the diet of UK beef cattle. This comprises fresh grass (74%) and conserved grass (17%), such as from hay, straw and silage. The remainder of the diet is made up of crop residues/co-products, grains, brassicas and fodder beet.

The UK has efficient beef production by international standards. Beef from other countries may be affected by emissions associated with land-use change, such as the removal of vegetation, including forests, to grow forage and feed. In the UK, both pasture and arable crop systems are managed to maintain yields and balance offtake and losses with nutrient application. Of those farms with cattle, 87% used a mix of housed and grazing systems for their cattle, with 9% having a year-round grazing system.[33] Improved animal nutritional management and breeding programmes have produced better feed efficiencies. There will be variations within the UK due to a range of factors, such as calving system and manure management.

When considering emissions only (i.e. ignoring carbon removal and sequestration), the UK suckler beef footprint is just less than half the global average, at 49% of emissions19, with less of a difference for dairy-bred beef (Table 1, above) at 78%. Footprints based on UK on-farm data are for 32.4 kg CO_2e/kg dwt and 22.1 kg CO_2e/kg dwt for suckler and dairy beef, respectively, though are much reduced, at 9.75 kg CO_2we/kg dwt and 9.06 kg CO_2we/kg dwt20, respectively, when GWP* is applied, owing to the contribution of enteric methane to the overall footprint and the national reduction in livestock numbers.

When looking only at GHG emissions, dairy beef has lower GHG emissions than suckler beef, due in part to dairy cow emissions being divided between beef and dairy co-products. Thus, the supply of dairy-bred beef is impacted by milk production, whereas beef herd emissions are attributed to the beef products only. In addition, the dairy-beef feeding ration has typically a higher energy density to encourage fat deposition which reduces time to finish and therefore lifetime methane emissions. However, the trade-off is a higher-quality diet which could lead to food-feed competition, if not based on crop by-products.

The carbon footprint of beef, however, only reports emissions and is based at best on national averages and at worst on global averages. The ARCZero project in Northern Ireland (see later) has shown us the huge impact the inclusion of carbon removal, sequestration and carbon stocks can have on the figures, and how different individual farms are. Two of the seven farms on that project were already beyond net zero, and one of those was a beef and lamb farm.

Sheep

Like cattle, sheep in the UK are also predominantly fed a grass-based diet. They are often farmed in hillier areas, particularly where cool summers and high rainfall make it unsuitable to growing crops. In these areas, they demonstrate considerable resilience in their ability to turn grass from marginal land into nutritious protein and vital micronutrients. Careful management of sheep grazing both in isolation or mixed with cattle enables the development of a mosaic of habitat in upland areas facilitating broader environmental benefits for both flora and fauna.

The UK sheep diet consists of 90% grass-derived feed – 60% from fresh grass and 30% from conserved grass – and the remainder from other co-products/forages.[34]

In Table 1 (above), the emissions for UK sheep meat (both lamb and mutton) are 6% lower than the global average, at 37.4 kg CO_2e/kg meat.19

The farm type or system greatly affects the emissions in UK lamb production. Lowland systems produce less emissions per unit of output than upland systems. This is owing to the system being more productive (more kg of meat) per hectare of land or per breeding ewe. The GHG emissions intensity of lamb produced by lowland systems was found to be 11 kg CO_2-eq/kg of liveweight, compared with 13–18 kg CO_2-eq/kg of liveweight for upland and hill systems, respectively, before carbon removal, sequestration and stocks are taken into account.[35]

As sheep are ruminants like cattle, enteric methane is also the greatest proportion of the carbon footprint, followed by emissions from fertiliser and manure application due to nitrous oxide. The farm production footprint under GWP* is much reduced as the impact of methane is adjusted, meaning that the carbon footprint becomes negative at -0.13 kg CO_2e/kg meat, predominately due to the significant reduction in sheep numbers in the UK over the last decade.

As with beef above, these numbers are reporting emissions only and are using national averages.

Pork

UK pig systems are different to those of ruminants, with 60% of sows housed indoors. Furthermore, 90% of indoor sows and 60% of finishing pigs are kept on straw. Pig diets are very much aligned with the circular economy, with just under 50% comprised of by- and co-products from food destined for human consumption.[36]

The pork product footprint is lower relative to that of ruminants of cattle and sheep, as pigs are monogastric and therefore do not produce as much methane from enteric fermentation as ruminants, with most methane from pig systems produced from the management of pig manures and slurries. However, the main emissions hotspot of the pork product footprint is from feed. GWP* figures are not currently available at the time of writing, although there would be less variation between GWP100 and GWP* for pork than observed for cattle and sheep due to the lower emissions of methane.

Table 1 (above) shows that the emissions average from UK pork product is slightly lower than the global one at 11.5 kg CO_2e/ kg meat and 12.3 kg CO_2e/ kg meat, respectively.18 The UK product emissions up to farmgate is 4.96 kg CO_2e/ kg pork.20

Farm production analysis LCA for the AHDB Pork Roadmap demonstrated a 22% decrease, from 6.20 to 4.86 kg CO_2e, between 2008 and 2017.[37] Pig farming accounted for 72% of the product carbon footprint from production to post-consumption.[38]

Higher growth rates and increased leanness over the period have been shown to lead to substantial reductions in energy requirements[39] for both indoor- and outdoor-bred systems. This analysis demonstrated that the change in feed composition had a greater effect than changes in animal performance.

Land use

Summary points

- Beef cattle and sheep in the UK are not big consumers of purchased feeds being as the majority of their diets are grass
- The UK imports approximately 1% of the world's total soya, with 90% of the UK imports being for animal feed[40]
- In 2019 62% of the soya imported to the UK was from sources at low risk of deforestation/conversion, with the eventual goal that this will be 100% in the coming years
- The majority of soya in the UK is fed to poultry due to its digestibility for monogastrics
- In total, 72% of agricultural land in the UK is permanent grassland, rough grazing or temporary grassland[41]
- Grazing ruminants have helped shape the natural landscape of the UK over centuries, playing a pivotal role in habitat management and enhancement
- Integrating grassland with grazing livestock has the potential to remove and sequester carbon, due to its extensive and diverse rooting system twinned with the above-ground biomass
- Converting existing grassland to arable land is not a straightforward solution, taking into account soil quality, topography and untended consequences, such as the release of carbon
- UK farmers are looking for other land management practices to integrate into their systems, such as the incorporation of trees and shrubs in agroforestry systems, enabling the continued grazing alongside tree planting, and the browsing of tree fodder where appropriate
- Livestock systems are the epitome of circular farming, enabling the careful use of by-products and nutrients to minimise waste and optimise output

Purchased feed

The largest association between meat production and rainforest loss is the indirect impact from the cultivation of soya for livestock feed in South America. The expansion of land use for this purpose is detrimental to important regions of biological diversity.

In 2019, net UK imports of both soya beans and cake were approximately 2.6 Mt, representing less than 1% of the world's soya. Over 90% of the imported soya is estimated to be for animal feed.[42] Of this, 17% was used for dairy cattle and 9% for pork, with the majority being used in broiler chicken production (53%). However, blending of soya with other feed is conducted at more than 50% of pig farms. Soya products currently offer good sources of protein for pigs due to the amino acids contained and their digestibility, which is greater than most alternative plant proteins available at present. The replacement of soya bean meal with protein not associated with land-use change has the greatest impact for reducing the overall carbon footprint of pig production.

The total proportion of soya imported into the UK in 2019 considered to be from sources at low risk of deforestation/conversion or covered by a deforestation- and conversion-free certified soya standard totalled 62%.[43] The eventual goal is for 100% deforestation-free and conversion-free sourced soya. The UK Roundtable on Sustainable Soya was established in 2018, with the goal of developing a secure and resilient supply of sustainable and deforestation-free soya to the UK. The forum comprises over 30 members, including major supermarkets, processors, farming organisations, feed businesses, foodservice businesses and soya traders.

In addition, the UK Soy Manifesto[44] is a collective industry commitment to verified deforestation- and conversion-free (vDCF) soya to be fully implemented immediately where possible and no later than 2025. It includes UK retailers and food processors representing 60% of UK soya consumption, as well as soya importers and the animal feed industry. At the time of writing, the proposed UK Forest Risk Commodity Regulation (UKFRC) will require larger businesses (>£50m turnover, > 500 tonnes of commodity use) to ban the use of a range of commodities, including soya and any products derived from them; if they are sourced from land linked to illegal deforestation, due diligence and annual reporting will be required.

It has been argued that animal protein could be partly replaced by that of legumes, such as beans and peas; this alternative often disregards the broader nutritional benefits of animal protein, and the bioavailability of certain nutrients in animal derived protein, such as B-vitamins, long-chain omega-3, iron and zinc. Increasing legumes in arable rotations can be beneficial and can help reduce the demand for nitrogen from synthetic fertilisers, as legumes form symbiotic relationships with nitrogen-fixing bacteria in the soil. They are also valuable as break crops in arable rotations, as well as providing biodiversity benefits. Faba bean and peas are currently the UK's major legume crops (267,000 ha in 2022).[45]

Nutritional quality aside, the area available for planting grain legumes in the UK is limited by frequency of legumes in the rotation and in turn by the type of legume and the other crops in the rotation. Soil type is also an influencing factor – for instance, peas are unsuited to heavy soils and beans to light soils.[46] Furthermore, alternative legumes for human consumption are not necessarily suited to UK climatic conditions. Phaseolus (navy/haricot) beans, used to produce the British staple baked beans, are not easily grown in the UK due to intolerance to cold soils, with warm and dry conditions needed at end of season. Demand is currently met by imports (estimated 50,000 t in 2020).[47,48] Lentils are a cool-season food legume, so they could further be adapted to UK conditions, though chickpeas have limited frost tolerance and need warm and dry seasons. Further developments in genetics and agronomy would be needed both for home-grown established and alternative legume crops to meet the protein requirements needed.

Grassland

Grazing is a key part of UK farming, and for many, management of livestock is integral to a way of life. It has shaped the uplands and helps determine which plants form the dominant vegetation over large areas. In the UK, 72% of agricultural land is permanent grassland, rough grazing or temporary grassland.[49] The raising of livestock for meat and milk optimises the management of the land and resources for both food production and ecosystem services, as well as being important for the rural economy, especially if the land is unsuitable for growing crops direct for human consumption. It is fundamental that these carefully managed landscapes are maintained and are protected from the temptation to afforest as severe land-use change to mass tree planting would undermine the ability to produce food alongside delivering ecosystems services.

Well-managed grazing lands provide habitats for shelter, feeding and breeding and help to enhance ecosystems and biodiversity. Indeed, the removal of livestock in certain UK landscapes could have detrimental impacts on land quality and flora and fauna biodiversity.

The introduction of species diversity within grassland, such as growing clover legumes in grass swards, has been shown to lead to a reduction in nitrous oxide emissions. Including multi-species mixtures of legumes and herbs in grassland can provide a range of agronomic and environmental benefits, including increased dry matter, improved animal performance, increased nitrogen use efficiency, weed suppression and greater resilience to drought.[50]

Integrating grassland with grazing livestock has a high potential to remove and sequester carbon, owing to its extensive and diverse root system and high turnover of above-ground growth. There can be variability due to different management practices, such as sward composition, fertiliser inputs, grazing management (reseeding and grazing or cutting), frequency of renovation and soil types.[51] Compared with arable and horticultural land, improved grassland holds 85% more carbon.51 Indeed, many studies have demonstrated the range of soil carbon stocks that can be accumulated below grassland. For instance, at a depth of 30 cm, carbon stocks range between 72 and 204 t C ha^{-1}, with a mean of 121 t C ha^{-1} beneath pasture with natural grasslands.[52]

Fertiliser inputs (manufactured and organic) in more intensive grassland systems can enhance carbon storage due to greater plant productivity, residue returns and root inputs to soil, although much of the extra productivity will also be removed as silage or animal biomass. Grazed grassland removes and sequesters more carbon than mown grassland due to the greater return of manure and nutrients. Furthermore, grazing alters the soil microbial community, which enhances the availability of substrate favouring carbon sequestration into the soil at depth.51

A long-term study of 43 years at an experimental grassland site in County Down, Northern Ireland, showed that soils receiving cattle slurry showed higher carbon gain and nitrogen retention compared with soils receiving the macronutrients via manufactured fertiliser or pig slurry. It was estimated that net rates of CO_2 sequestration in the top 15 cm of the soil can offset 9–25% of GHG emissions (CO_2e) from intensive management. The lowest rate of sequestration was achieved with the fertiliser control, and the highest was achieved with the greatest rate of cattle slurry application.[53]

Moreover, inclusion of grass swards in arable rotations can have positive effects on arable yields, as well as benefits to soil carbon stocks. This grass is typically used as livestock forage, either as grazing land or as a cut-and-carry forage crop.[54] The benefits to soil and yield are long term and may take up to 120–130 years to be fully realised.[55]

It is not straightforward to simply replace established grasslands with arable land in order to produce food directly for human consumption, and there are many complex challenges that need to be considered. For example, such a change in land use would release carbon, with a considerable loss of soil organic carbon (SOC) widely recorded. Also, the topography, e.g. the gradient, high flood risk or climate, e.g. humidity, may be unsuitable. It is estimated by the UK Met Office that in many grassland regions, the soil is at field capacity (i.e. the amount of soil moisture or water content held in soil after excess water has drained away) for more than 200 days per year, which is at least 90 days longer than major arable regions in the UK. Agricultural land is classified in England and Wales using the Agricultural Land Classification (ALC) system which provides a method for assessing the quality of farmland, and its ability to be used for certain types of food production. The ALC system classifies land into five grades, with 1 being the best and 5 being the worst, with the best land being capable for cropping. Most grassland is at grade 4 and 5, and so it would not be as productive if converted as existing arable land; this would have implications for sowing, agrochemical application and associated run-off and harvesting and would have subsequent effects on grain quality and therefore profitability. Furthermore, there may be practical considerations, such as the proximity to processing infrastructure in the supply chain and field access to large machinery (e.g. combines down narrow country lanes and hedge lined fields).[56]

Agroforestry

Farming systems may also incorporate agroforestry, where the land management combines agriculture and trees, hedges and shrubs. Livestock may be integrated with a grassland-based agroforestry system, known as silvopasture. As well as removing and sequestering carbon and encouraging biodiversity, the trees can provide shelter and shade for livestock in the face of drought and extreme rainfall events.[57] Silvopasture agroforestry comprises systems in which trees and/or shrubs are grown in grazed pasture. The Woodland Trust (2022)[58] has estimated that if established on 30% of grassland, UK net zero could be achieved in 2051. Moreover, post 2051 carbon sequestration was shown to exceed emissions for the entire UK grassland area, i.e. net negative. Whereas under a scenario where 50% of UK grassland is converted to agroforestry based on 400 trees/ha, net zero is achieved seven years earlier, by 2044. This enabled the rate of sequestration to be high enough for all emissions from UK grassland to be negated by 2063.

Circular farming

Livestock systems play a key part in circular farming through converting surplus arable and grass products into valuable food, fibre, pharma, energy and fertiliser. They can also influence soil organic carbon stocks via manures or slurries due to the range of carbon inputs and microbial functioning that can affect ecosystem services overall. Organic amendments can have profound effects on soil structure, soil chemistry and soil organisms (microbes and macrofauna) and have also been found to suppress soil pathogens and disease. Strategic management of animal manures can thus be a cost-effective way to increase soil organic matter content, stimulate soil biology, improve physical structure and, ultimately, improve crop yields. However, attention should be given to the application rate and timing to minimise potential negative effects, such as nitrous oxide, ammonia and nutrient loss from soils. These are addressed by several regulations and good practice across the UK. A higher level of soil organic carbon (SOC) stock is associated with a better animal performance and less nutrient losses into watercourses.[59]

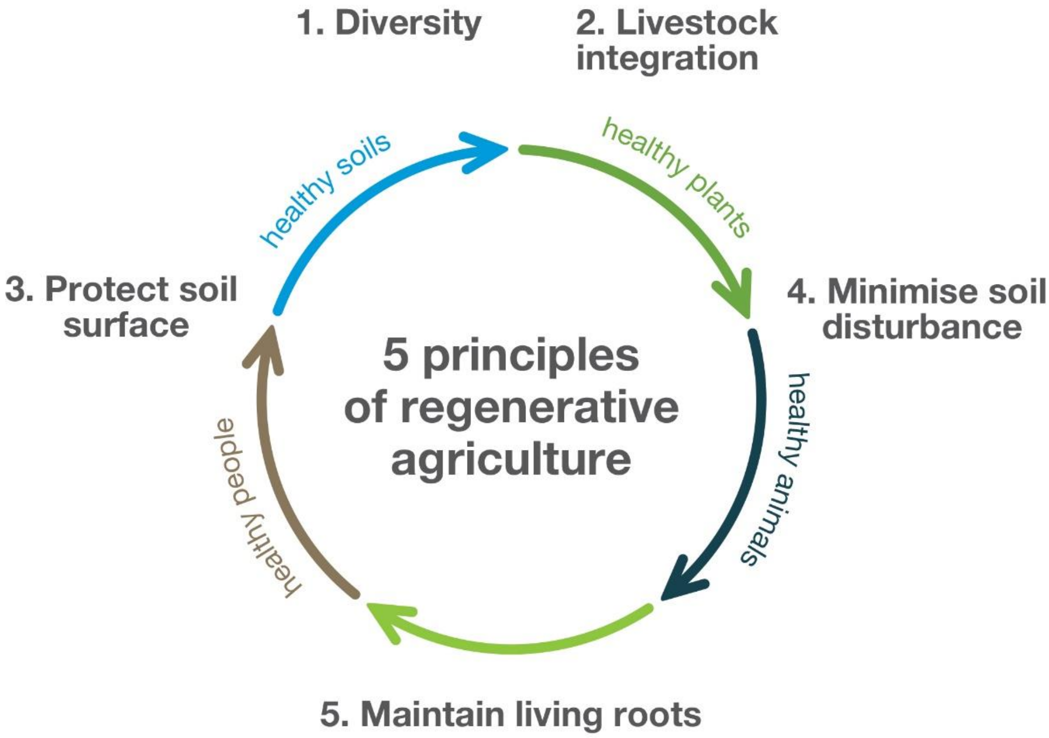
It is estimated that 1 kg of plant-based food production generates at least 3–5 kg of crop material that is not suitable for human consumption but is suitable as feed for animal production.[60] Thus, there is a need for strategies to manage and recycle plant nutrients. In a given agricultural area, livestock systems deliver high-quality food protein micronutrients and calories equivalent to 50–100% of primary plant-based food. In addition, livestock do not compete with humans for non-edible crop material. The resulting protein of animal origin has a higher nutritional value (DIAAS) than protein in the plant-based animal feed.

Any losses in food production must be mitigated by maximising the feed efficiency of non-human edible material. Livestock have a central role in diverting what would be deemed waste from the food supply chain into animal feed, e.g. processing co-products from wheat[61], therefore complementing production of plant-based food. It has been demonstrated that it is a low-cost option, with the potential to reduce GHG emissions and land use. All these co-benefits take advantage of what livestock naturally do well.

Waste and Resources Action Programme (WRAP) estimated that 660,000 tonnes of UK food waste (2016), both from retail and manufacture, were being used for animal feed – equivalent to 93% of the total food surplus.[62] Their analysis for 2025 suggested that 860,000 tonnes of food surplus could be suitable for use in animal feed, therefore redistributing what could be going to waste, and helping to contribute to the Courtauld Commitment – an industry collaboration and agreement to reduce food waste, GHG emissions and water stress.[63]

Regenerative agriculture encompasses several farming practices, including no-till, cover cropping, diversified rotations and the integration of livestock into farming systems, and in the process minimise waste. These practices can improve soil quality and may deliver additional benefits, such as mitigation of climate change and enhancement of biodiversity. Thus, they have been cited in the objectives of many international agri-foods companies.

Figure 5. Groundswell 5 principles



Source: Groundswell Agriculture Ltd. (**www.groundswellag.com**), redrawn by AHDB

A qualitative study in the north of England indicated that livestock are key in regenerative farming systems. This was associated with the right grazing management strategy appropriate to the farm's soil, climate, livestock and stocking rates. Farmers highlighted using mob grazing and using livestock on leys or cover crops, e.g. using sheep to graze cover crops over winter instead of destroying them by other means.[64]

Case study: Livestock in the rotation[65]

Balbirnie Home Farms in Fife gathered scientific data behind its regenerative farming approaches over a six-year project, with years 2021–2023 as part of **AHDB's Strategic Cereals Farms** network.

Farms Manager David Aglen has explored the effect of regenerative practices at scale in the natural environment on a commercial farm. The 1200 ha area Balbirnie Home Farms grows mostly winter wheat and spring barley, as well as oats, winter barley, potatoes and carrots on a seven-year rotation. The 200-head beef suckler herd has been moved on to a wholly outdoor grass-fed system as part of an aim to improve soil health. The herd carries a Pasture for Life[66] certification – a mark that certifies that meat and dairy originate from animals raised only on grass and pasture.

The integration of livestock has provided a considerable benefit to the farm business. Large mobs of sheep are kept on small areas of the winter-sown arable fields for a short period, grazing enough to take the growth down but not too long as to hinder the root mass. This measure has helped reduce the need for and costs of nitrogen and fungicide, as well as of winter feeding and housing.

"Livestock is part of our toolbox of reducing the need for nitrogen and fungicide," according to David. "It's easy to tell where there hasn't been livestock in the rotation as we need more chemicals to manage the crops." As the cattle are outside all year round, it has reduced costs on concentrated feed and labour on both bruising the feed and feeding indoors. Forage crops are grown to feed the cattle through the winter, which brings diversity into the rotation and reduces the disease pressure. The overall approach has prioritised plant and soil nutrition, reduced reliance on chemical inputs and has demonstrated the potential to reduce variable costs across different crops by up to £200 per hectare. For further information, please refer to the **full case study**.65

Natural resource management

Summary points

- Farms play a key role in managing natural resources and delivering ecosystem services
- It is important to differentiate between farming systems that utilise the majority of their water from direct rainfall (green) and those that rely on mains water (blue)
- The UK's maritime climate, and concentration of livestock in the west of the country, ensures that natural water supply from rainfall is utilised in these food production systems
- Alongside GHGs, farmers also have to navigate other pollutants to air and water, such as ammonia, nitrogen and phosphorus, ensuring that their systems minimise the amount emitted
- UK farmers play an important role in managing and enhancing both below and above-ground biodiversity
- Ruminants play a unique role in enhancing certain habitats through conservation grazing practices

Water

English beef has a water footprint of 17,700 $m^3\ t^{-1}$ carcase weight and lamb 57,800 m^3/t^{-1}.[67] Of these, 84% and 97%, respectively, are green water use, i.e. rainfall on crop and grassland. Without this breakdown, there is no differentiation between rainfall and irrigation (mains water) supply (blue water), which means that UK beef production may appear similar in impact compared with countries where irrigation of feed crops is prevalent. This stresses the importance of considering the type of water used and not purely the total amount. For a temperate, wet climate such as England, crop and grassland water requirements are adequately met by green water from rainfall. Upland and hill production systems have higher water footprints, mostly because grass yield is lower. However, rainfall surplus per tonne of grass production is still highest in these regions, so export of water for other purposes is possible.48 Thus, the effects of using water in food production depends on the water source and the amount available. In the UK, most beef production is concentrated in south-west England, Cheshire, north-west England, Wales, Scotland and Ireland, which are all wetter parts of the British Isles.

Globally, for pigs, a water footprint of 3,831 $m^3 t^{-1}$ (water footprint of live animal at end of lifetime) has been estimated. This again is dominated by green water, but with a larger proportion of blue water than for the grazing ruminants due to the greater amount of feed consumed, the variation between the quantity of green and blue water is dependent on whether the crops to feed pigs require irrigation or not. Globally, pigs have a lower water footprint overall than beef cattle, partly owing to the better feed conversion ratio of pigs and therefore production efficiency.[68]

Air

Ammonia is inherently produced from the amalgamation and breakdown of livestock urine, faeces and nitrogen fertilisers. It is the dominant acidifying emission in agriculture, whereas sulphur dioxide is the dominant gas for post-farm processes. A significant amount of UK agricultural ammonia emissions is in low concentrations and is not harmful to human health. However, it can react with other compounds in the air to form secondary particulate matter and can pose a risk to people's health and farm habitats. Measures to reduce ammonia will have direct environmental benefits.[69] The Government is committed to a 16% reduction in ammonia emissions by 2030 (2005 baseline).[70]

Farmers have been reducing ammonia emissions, for instance, by using protein more efficiently in the diet, frequent cleaning of livestock areas, covering slurry stores, using low-emission spreading techniques and carefully managing any urea-based fertiliser. In the 2023 Defra Farm Practices Survey7, 53% of farmers stated that they were improving efficiency in manure/slurry management and application. The number of livestock farmers planning to enlarge, upgrade or reconstruct their manure or slurry storage facilities has risen steadily from 14% in 2019 to 22% in 2023 – of these, 71% are planning to make these changes within at least three years, while 89% have at least four months' slurry (the amalgamation of livestock urine and faeces) storage capacity and 49% have seven or more months' slurry storage capacity.7

In the UK, intensive pig units fall under the Industrial Emissions Directive and must apply best available techniques (BAT) on their farms, including technologies used in housing. These regulations came into force in 2008, and the target date for all large farms to achieve these standards by was 2021. This was preceded by controls through the Pollution Prevention and Control Act (1999). AHDB conducted a comprehensive study of ammonia emissions from different pig production systems between 2019 and 2020[71] to improve the industry's understanding of emissions from the pork sector and to indicate where ammonia reductions could be made. As a result, emissions factors for environmental permitting were revised and benchmarks were provided from which further reductions could be made. Industry and Defra co-developed the Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions, which explains the practical steps that can be taken.[72]

Emissions from agriculture accounted for 87% of total ammonia emissions in 2022 and have decreased by 17.4% since 1990, and by 2.6% since 2005. Furthermore, 67% of the agricultural ammonia emissions are from livestock, with 18% coming from fertiliser application.70

Nitrogen is another critical component of our agricultural systems, with food production dependent on the cycling of nitrogen in the rural environment. However, nitrogen loss, either from livestock, manures or fertiliser application, can lead to issues when that loss is in gaseous forms such as nitrous oxide or ammonia, or through nitrates draining into run-off water.

Nitrogen aids the growth of most plants but can also damage plant species that desire low nitrogen concentrations. These species then find themselves out-competed by the species that can utilise nitrogen more effectively, leading to biodiversity loss, soil acidification and changes in ecosystem structure and function.

Soil nutrient balances estimate the annual nutrient loadings of nitrogen and phosphorus to agricultural soil. These indicate the potential risk of losses of nutrients to the environment, which can affect air and water quality, e.g. eutrophication, as well as climate change. The UK nitrogen and phosphorus balances in 2022 were the lowest observed since 2000, thought to be brought about by lower inputs from inorganic fertilisers because of high prices; however, nitrogen and phosphorus from manure does contribute to eutrophication. Thus, reducing the excretion of nitrogen and phosphorus is of utmost importance.

In 2023, over two-thirds (69%) of livestock farmers routinely tried to keep livestock out of watercourses, and this has risen steadily since 2019.7 Nitrogen and phosphorus inputs have decreased across the following livestock sources between 2000 and 2022 (see Table 2).

Table 2. Nitrogen and phosphorus input changes for UK, 2000–2022[73]

Total inputs associated	Nitrogen (% change in thousand tonnes of N)	Phosphorus (% change in thousand tonnes of P)
Cattle	-17	-17
Sheep and goats	-22	-22
Pigs	-24	-25
Livestock manure production	-16	-16

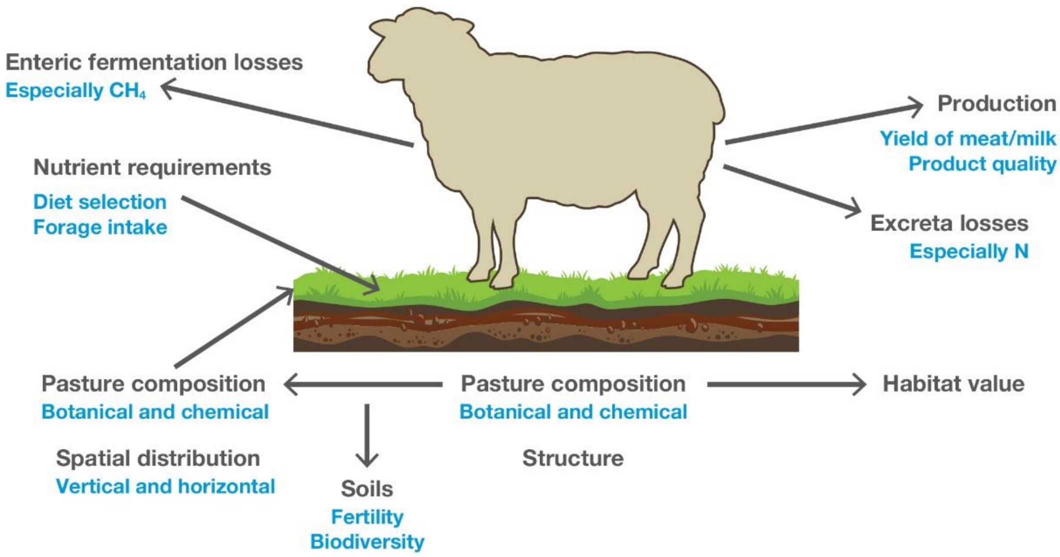
These decreases have resulted from reductions in the application of both inorganic manufactured fertiliser and cattle manure.

Biodiversity

Grassland systems can deliver many ecosystem services, which are the direct and indirect contributions that ecosystems provide to humans, including biodiversity, erosion control and climate regulation (summarised in Figure 5).[74] Livestock positively impact biodiversity through the effect on sward structure, plant composition and distribution, which in turn affects the habitat value of the grassland for other groups, such as invertebrates, birds, reptiles and small mammals. Grazing can enhance biodiversity by creating a patchier environment within fields, which in turn provides micro-habitats within the sward that can be used by different types of plants and animals. The diversity can be produced within and between paddocks and fields, as well as at a landscape or catchment scale.

Ruminant grazing can be particularly beneficial for creating and maintaining suitable habitat for different animal species, including ground nesting birds. In some instances, biodiversity gain can be achieved with improved pasture utilisation, and related production efficiencies can lead to lower GHG emission intensities and decreased feed costs. Management strategies should adapt to environmental conditions to help maintain biodiversity in grassland.[75]

Figure 5. Summary of the main plant–animal interactions within a grassland system[62]



Source: AHDB

Sheep tend to be more selective grazers than larger animals like cattle. When the availability of preferred resources declines, larger animals are faster to change to eating less-preferable sward parts, due to their higher forage requirements. As a consequence, their behaviour can be effective in controlling competitive plant species that are left by the more selective grazers. It has been demonstrated that low-intensity grazing of both cattle and sheep can improve the diversity and abundance of a range of plants within grazing systems.75

It has been found that 25% of biodiversity (species) is below ground. A recent study has confirmed that the cessation of grazing causes below-ground biodiversity loss, in terms of soil microbes and fauna, and found that some of the healthiest soils are in areas grazed by livestock. This reinforces the important role that grazing animals have for maintaining the diversity of soil communities, which is pivotal in the functioning of ecosystems.[76]

What next?

Summary points

- The livestock sector is working together across the entire supply chain to progress environmental sustainability through partnerships and collaborations
- The sector is working together to enhance the volume and quality of farm-level environmental data, ensuring that it reflects what is happening on UK farms rather than global averages
- UK farmers will continue to embrace farm management practices that seek to reduce their carbon footprint and improve their broader environmental sustainability
- UK livestock agriculture has an important role to play in providing nutritious sustainable food to a growing global population
- The UK livestock sector is taking a proactive 'no-regret' approach taking action to address mitigations that are cost effective and appropriate based on today's science in consistently tacking climate change at farm level

The whole agricultural supply chain is committed to progress environmental sustainability both in practice and in evidence. Examples of collaborations across the industry to drive environmental performance include Meat in a Net Zero World[77], which is a commitment from across the UK meat production and supply chain, including the major retailers and producers. The aims are to improve efficiency and productivity, minimise waste, protect natural assets and reduce GHG emissions. Positive actions are implemented by supply chain businesses (processors, retailers, hospitality and foodservice businesses), with support from industry bodies. The collaboration, facilitated by WRAP, seeks to make the UK meat industry a world-leading example of efficient and sustainable meat production and supply. This covers sourcing raw materials for use in feed that is cultivated in a way that protects against conversion of forests and valuable native vegetation, as well as reducing operational food waste. Progress to date includes more than 60% of the committed businesses having set net zero or science-based GHG reduction targets that encompass the whole supply chain, including agricultural production (Scope 3) emissions. New farm-level metrics to help track progress against these and national-level targets have been agreed for poultry, pigs, beef and lamb. Research and knowledge transfer activities continue.

In addition, there is the UK Cattle Sustainability Platform (UKCSP).[78] The UKCSP comprises over 26 organisations that span the supply chain from farm to fork. Involvement of any organisation with an interest in improving the sustainability of beef production in the UK is welcomed. The collective target is an intensity reduction of 15% in GHG emissions by 2025, with the aim of fixing a future target that recognises both reduction strategies and sequestration within beef production. There is also a need to further connect farmers and supply chains as sustainable net zero is pre-competitive and for everyone's benefit. The 'Application of Science Report to realise the potential of the agricultural transition' recommended the coming together of many disparate demonstration farm networks to work together to realise a sum greater than the sum of its part – this is being realised through the School of Sustainable Food and Farming's Sustainable Farm Network, supported by AHDB and the industry.

Data that is more representative of UK farming systems and production is required and therefore sourcing that at farm level is vital. Collectively, it gives crucial primary data to inform IPCC tier 3 methodology, resulting in more accurate product or commodity assessments, such as LCAs, as well as providing evidence that better reflects environmental performance at a national level. Defra, through their Food Data Transparency Partnership (FDTP), is bringing the supply chain together to deliver consistent, accurate and accessible environmental impact quantification for the agri-food industry.[79]

Opportunities

The livestock arm of the UK Agritech Centre (formerly CIEL (Centre for Innovation Excellence in Livestock)) has identified a number of key emerging technologies and innovation in livestock, where research has demonstrated that GHG emissions can be considerably reduced in the goal of meeting net zero.[80]

- Genetics could be deployed to target methane emissions specifically from enteric fermentation, together with the development of genetic tools to manage the rumen microbiome. Further research and funding opportunities include increasing the collection of methane emissions performance data (phenotypes) and the use of restricted selection indices
- Enteric methane may also be targeted using methane inhibitors or vaccines. There are a range of commercial methane-suppressing products at various stages of market entry or availability. These present potential emissions reductions of 12–37%, with safe and high-efficacy products anticipated to enter the UK market from 2025. Although vaccines are at early development stages, they have shown promising results in New Zealand. Models for the UK estimate an annual reduction in methane from livestock of 30% (6.8 $MtCO_2e$) in a best-case scenario. However, it must be highlighted that the widespread impact of inhibitors is still undetermined with concerns in relation to how their impact could be measured in a widespread way, how the feed additives could be fed to grazed animals, what, if any, unintended consequences there would be in relation to yield or fertility, and who within the supply chain pays for their use
- The use of rapid on-farm disease diagnostics can improve efficiency and bring environmental benefits through improved water quality, lower ammonia emissions and reduced water usage. The continuation of vaccination against endemic animal diseases or the use of prophylactic (preventative) health products (PHPs) could increase productivity and therefore resource use and emissions
- The replacement of soya with low-carbon, less resource-intensive novel protein feeds and processed animal protein can significantly reduce emissions. However, further research is needed to assess production impacts at scale and ensure nutritional consistency and safety
- Innovative methods like plasma treatment of slurry could bring about significant reductions in ammonia and methane but would require a low-carbon energy source to minimise the carbon footprint. Manure additives and improved data-capture systems at farm level would help to advance nutrient management

These technologies should be combined with the following enablers to drive innovation and maximise uptake: 1) farmer engagement and capacity building, 2) enabling regulation and policy, 3) effective financial flows and 4) supply chain and cross-sector collaboration – many of which are already taking place.

Livestock farms are already implementing a range of measures to improve environmental performance. GHG emissions are being lowered through actions that improve performance or efficiency of animal production, as demonstrated in the Defra Farm Practices Survey 2023.7 For example:

- In total, 73% of livestock farms had a farm health plan (FHP), and most of these were written or recorded. Health planning helps to prevent disease and in doing so improve the performance of livestock, for instance reaching finishing weights earlier and achieving higher feed conversion rates

- High sugar grasses can also help to improve production efficiency, such as improved milk yields and faster live weight gain. In total, 59% of livestock farms with temporary grassland had sown high sugar grasses, which can aid utilisation of nitrogen from the grass and thus reduce losses in livestock excretion
- Sowing temporary grassland with a clover mix can reduce the amount of nitrogen applied and thus reduce the demand for synthetic fertiliser, as well as improving grass yields. However, it is not suitable for all soil types. In total, 74% of livestock holdings stated that a proportion of their temporary grassland had been sown with a clover mix. Feed intake and type of feed can impact productivity and efficiency and therefore GHG emissions
- In 2023, 71% of livestock holdings used a ration formulation programme or nutritional advice when planning the feeding regime of their cattle and sheep
- Furthermore, the majority of livestock farmers (72%) always take action to reduce stocking rates when fields are excessively wet to reduce emissions via soil compaction and subsequently from reduced manure deposition33

Environmental baselining

Four years ago, a group of seven farmers across Northern Ireland came together to pilot what the journey to net zero looked like for UK agriculture. Comprising of arable and livestock farms, the group secured funding to baseline their own numbers to enable integrity in understanding the starting point on their journey. This enabled them to identify where their emissions were coming from and how to reduce them and where their carbon stocks were in their landscape and how to increase them.

Results of the project were a revelation, for the first time showing in hard numbers the net-carbon position of each of the seven farms (Table 3). It demonstrated that not only are some farms almost at net zero but some were beyond it – taking more GHGs out of the atmosphere than they put in. Contrary to modern scientific papers and models, the two farms beyond net zero raised cattle or sheep. It revealed how those farm systems with reduced capacity to reach net zero would rely on those farming systems that can go beyond it to help the industry as a whole to achieve net zero.

Table 3. Net carbon as a percentage of gross emissions on ARCZero farms

2021 Agrecalc analysis	Enterprises	TIER 2 EMISSIONS MODULE	TIER 1 SEQUESTRATION MODULE	Net emissions t CO_2-e/yr	% Reduction of gross emissions
		Gross emissions t CO_2-e/yr	Gross sequestration t CO_2-e/yr		
Ian McClelland	Dairy	1,101	309	792	28%
Hugh Harbison	Dairy	2,009	549	1,459	27%
John Egerton	Beef and sheep	1,475	444	1,031	30%
Roger and Hillary Bell	Sheep with beef	754	456	298	60%
Simon Best	Arable with beef	1,799	738	1,061	41%
Patrick Casement and Trevor Butler	Beef and sheep	492	548	-56	111%
John Gilliland	Willows and dry cows	151	156	-4	103%

Source: ARCZero Arc-Zero-Final-Report.pdf (cafre.ac.uk)

Additionally, the soil data showed that too simplistic an approach to food production and land management can lead to undesired consequences in our desire for environmentally sustainable food production. As with nutrition and diets, variation is key. ARCZero also showed how monocultures, or single-crop agriculture, including trees, have the poorest soil quality and biodiversity scores, whereas landscapes with multiple species and, most critically, grazing livestock had the highest soil quality and biodiversity scores. This is particularly significant as 25% of world biodiversity is in the soil.[81]

Among the seven farms, over 500,000 tonnes of carbon is locked up in the landscape in stocks, with over 90% of that in their soils, not their biomass, which raises questions on the best course of action to increase nationwide sequestration (Table 4).

Table 4. Total carbon stocks across ARCZero farms

Total ARC Zero CO_2 stocks	Enterprises	Soil carbon (t)	Tree carbon (t)	Total carbon (t)	% C in soil
Ian McClelland	Dairy	31,813	1,310	33,123	96
Hugh Harbison	Dairy	68,054	1,969	70,023	97
John Egerton	Beef and sheep	31,813	1,310	33,123	96
Roger and Hillary Bell	Sheep with beef	50,819	668	51,507	98
Simon Best	Arable with beef	237,915	6,493	244,407	97
Patrick Casement and Trevor Butler	Beef and sheep	54,556	4,022	58,578	93
John Gilliland	Willows with dry cows	19,468	4,937	24,405	80
			Total	**515,166**	

Source: ARCZero

Net zero vs zero hunger

In late 2023, the FAO outlined its Global Roadmap[82] to achieving global zero hunger within the 1.5˚C global temperature rise, plus a report on livestock pathways to net zero.[83] The comprehensive reports outlined scientific and pragmatic goals to ensuring environmental action and worldwide food security do not conflict. Modelling to assess the greatest impact each mitigation action could bring to reduce emissions demonstrated that global dietary change had one of the lowest reduction impacts, just ahead of energy use and manure management. While globally, the dietary change has one of the lowest reduction impacts, the FAO highlights the potential in environmental gain in a true-cost accounted method in developed countries if diets transition.[84] Alternatively, improved productivity driven by efficiencies would have, by far, the most impact on reducing emissions, followed by focused breeding strategies and proactive animal health management, especially in Africa and Asia.

Given this, and the need for 70% more food by 2050, the FAO goes on to determine that a 1.7% annual rise in livestock productivity is required globally to achieve zero hunger targets.22 Most of that increase will come from countries such as the UK, where extreme weather will be least impactful and where livestock production is among the most sustainable in the world, offering the unique opportunity to contribute to global food security, and delivering zero human hunger, while protecting and enhancing the environment.

Glossary

Acidification A measure of the impact from acids emitted to the atmosphere and deposited in water and soil. These can be ammonia from slurry/manure, or sulphur dioxide (SO_2) from the combustion of fossil fuels, which have the potential to react with water in the atmosphere to cause a change in acidity. Any change from the natural pH can have detrimental effects on plant and aquatic life.

Agroforestry Land use that integrates woody vegetation (trees or shrubs) into agricultural crops and/or livestock production on the same piece of land to benefit from the resulting ecological and economic interactions.

Carbon sequestration The removal and subsequent ‘long-term’ storage of carbon dioxide (CO_2) from the atmosphere by nature. If the carbon dioxide sequestered is more than the carbon dioxide emitted, the store is increasing and is known as a carbon sink.

Climate change A measure of the adverse impact of greenhouse gas (GHG) emissions that cause heat to be trapped in the atmosphere and results in a temperature rise of the Earth’s surface. GHGs include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), among others. The main consequence of climate change is global warming, which results in increased temperatures and regional climate changes.

Emissions intensity The amount of emissions per unit of output.

Eutrophication A measure of nutrient pollution in aquatic ecosystems, typically generated from phosphorus or nitrogen compounds through sewage, storm water run-off, fertiliser or manure. This can lead to excessive microbial consumption, which in turn results in oxygen depletion. Oxygen depletion can result in short- or long-term damage and potentially death to organisms that are exposed.

Field capacity The amount of soil moisture or water content held in soil after excess water has drained away.

Finishing pigs The phase of pig production where pigs are fed to reach market weight.

Global warming potential (GWP) This describes how much impact a gas will have on atmospheric warming over a period of time compared with carbon dioxide. Each greenhouse gas has a different atmospheric warming impact, and some gases remain in the atmosphere for longer than others. Carbon dioxide (CO_2) has the lowest warming potential, is the most abundant and lasts for thousands of years, so it is used as the baseline. The most commonly used GWP measure is GWP100, meaning the average warming potential over 100 years.

GWP* This is an alternative GWP, which better takes account of the warming impact of short-lived gases such as methane and the change in rate of emissions over time.

IPCC Intergovernmental Panel on Climate Change. This is the United Nations body for assessing the science related to climate change.

IPCC tiers A tier represents a level of methodological complexity. Usually, three tiers are provided. Tier 1 is the basic method, tier 2 is intermediate and tier 3 is the most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher-tier methods and generally considered to be more accurate.

Life cycle assessment (LCA) A methodology or process to assess and evaluate the environmental impacts of a product across all stages of its life cycle.

Mob grazing Grazing with a high density of stock for a short duration, coupled with a long rest period.

Nutrient balance The difference between the inputs and the offtake for each nutrient.

Nutrient inputs The total amount of inputs of each nutrient to the soil. This can be through application of mineral fertilisers or organic manures, atmospheric deposition, or biological fixation.

Nutrients The key macronutrients required for crop growth, such as nitrogen and phosphorus.

Offtake The total amount of nutrients removed from the soil by the growth of crops, which are either harvested or grazed by livestock.

Regenerative agriculture Regenerative agriculture encompasses several farming principles, including maintaining a healthy soil, reducing soil disturbance, e.g. no-till, covering the soil surface, e.g. cover cropping, diversifying rotations and integrating livestock into farming systems.

Ruminants Mammals that obtain nutrients from plant material through a symbiotic relationship with anaerobic microorganisms in the fore-stomach which ferments the feed and in so doing provides energy and protein to the mammal, but as a by-product produces methane gas.

Silvopasture Integration of trees with grazing animal systems.

Suckler beef This originates from cows kept especially for the production of beef, rather than milk. Their calves stay with the herd and are allowed to be fed by the mother of the calf. Suckler cows keep their offspring with them until the calves are ready to be sold, either for fattening or to a meat factory for beef.

vDCF soya Verified deforestation- and conversion-free soya.

References

1. Defra, (2023). Structure of the agricultural industry in England and the UK at June 2023 https://www.gov.uk/government/statistics/agricultural-land-use-in-the-united-kingdom/agricultural-land-use-in-united-kingdom-at-1-june-2023
2. Defra, (2022). https://www.gov.uk/government/statistics/agri-climate-report-2022/agri-climate-report-2022
3. FAO, (2023). Pathways towards lower emissions – A global assessment of the greenhouse gas emissions and mitigation options from livestock agrifood systems. Rome. Pathways towards lower emissions (fao.org)
4. Defra, (2021). Structure of the agricultural industry in England and the UK at June https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june#history
5. Defra, (2022). Agriculture in the United Kingdom 2021. National statistics Chapter 8: Livestock – GOV.UK (www.gov.uk)
6. Climate Change Committee, (2020). Land use: Policies for a Net Zero UK – Climate Change Committee (theccc.org.uk)
7. Defra, (2023). https://www.gov.uk/government/statistics/farm-practices-survey -february-2023-greenhouse-gas-mitigation
8. Global Methane Pledge. Homepage | Global Methane Pledge
9. FAO, (2023). Achieving SDG 2 without breaching the 1.5°C threshold: A global roadmap, Part 1 (fao.org)
10. DESNZ, (2021). Net Zero Strategy: Build Back Greener. assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf
11. DESNZ, (2024). Final UK greenhouse gas emissions national statistics: 1990 to 2022
12. FAO, 2023. (FAO) – News Article: Key facts and findings
13. AHDB, (2023). What is GWP*? | AHDB
14. Lynch, J., Cain, M., Pierrehumbert, R. and Allen, M., (2020). Environmental Research Letters, Volume 15, Number 4. https://iopscience.iop.org/article/10.1088/1748-9326/ab6d7e
15. AHDB, (2023). Applying GWP* to UK national GHG emissions | AHDB

16. NASA. Global Climate Change – Vital signs of the planet. Methane | Vital Signs – Climate Change: Vital Signs of the Planet (nasa.gov)
17. FAO. (2023). Methane emissions in livestock and rice systems – Sources, quantification, mitigation and metrics. Rome.
18. Climate Change Committee (CCC), (2017). Understanding the UK greenhouse gas inventory an assessment of how the UK inventory is calculated and the implications of uncertainty. NPL REPORT CSSC 0001 (theccc.org.uk)
19. Poore, J. and Nemecek, T., (2018). Reducing food's environmental impacts through producers and consumers. Science 360, 987–992. DOI:10.1126/science.aaq0216
20. Agrecalc, (2024). 2018–2022 Data extracted from Agrecalc Carbon calculator data of livestock systems
21. McAuliffe, G.A., Takahashi, T., Beal, T., Huppertz, T., Leroy, F., Buttriss, J., Collins, A.L., Drewnowski, A., McLaren,S., Ortenz, F., v.d. Pols, J., v Vilet, S., Lee, M.R.F. (2022). Protein quality as a complementary functional unit in life cycle assessment. *International Journal of LCA. https://doi.org/10.1007/s11367-022-02123-z*
22. UN Net Zero Coalition Net Zero Coalition | United Nations
23. Statista. Agriculture emissions worldwide – statistics & facts https://www.statista.com/topics/10348/agriculture-emissions-worldwide/#topicOverview
24. UNECE, Carbon Sinks and Sequestration Carbon Sinks and Sequestration | UNECE
25. Anthony, M.A., Bender, S.F. and van der Heijden, M.G.,(2023). Enumerating soil biodiversity. Proceedings of the National Academy of Sciences, 120(33), p.e2304663120. https://www.pnas.org/doi/full/10.1073/pnas.2304663120
26. Drewnowski, A., Rehm C.D., Martin, A., Verger, Eric O., Voinnesson, M., Imbert, P., (2015). Energy and nutrient density of foods in relation to their carbon footprint, The American Journal of Clinical Nutrition, Volume 101, Issue 1, January 2015, Pages 184–91. Energy and nutrient density of foods in relation to their carbon footprint – ScienceDirect
27. Lee, M.R.F., McAuliffe, G.A., Tweed, J.K.S., Griffith, B.A., Morgan, S.A., Rivero M.J., Harris, P., Takahashi, T., Cardenas, L. (2021) Nutritional value of suckler beef from temperate pasture systems, Animal, Volume 15, Issue 7, July 2021. https://doi.org/10.1016/j.animal.2021.100257
28. McAuliffe, G. A., Takahashi, T., & Lee, M. R. F., (2018). Framework for life cycle assessment of livestock production systems to account for the nutritional quality of final products. Food and Energy Security, 7(3), [e00143]. https://doi.org/10.1002/f es3.143
29. FAO, (2023). Pathways towards lower emissions – A global assessment of the greenhouse gas emissions and mitigation options from livestock agrifood systems. Rome. Pathways towards lower emissions (fao.org)
30. Defra, (2023). Farm Practices Survey February 2023 – greenhouse gas mitigation – GOV.UK (www.gov.uk)
31. Management PTAs | AHDB
32. AbacusBio, (2022). Scoping study: Delivering a vision for improving the beef and sheep sectors through animal breeding over the next 10 years. | AHDB
33. Defra, (2019). Cattle_Farm_practices_survey_April_2019-12sep19.pdf (publishing.service.gov.uk)
34. FAO, (2020). Global Livestock Environmental Assessment Model – interactive GLEAM-I model. http://gleami.org/input
35. CIEL, (2021). Net Zero Carbon and Livestock.
36. National Pig Association, 2020. NPA briefing note on soya use in the pig industry. NPA Report (npa-uk.org.uk)
37. ERM, (2018). Streamlined Life Cycle Assessment of British Pork Final Report, Prepared for AHDB
38. BPEX, (2014). Positive Progress, An Update on the Roadmap for the environmental sustainability of the English Pig Industry.
39. Ottosen, M., Mackenzie, S.G., Filipe, J.A.N., Misiura, M.M., Kyriazakis, I., (2021). Changes in the environmental impacts of pig production systems in Great Britain over the last 18 years, Agricultural Systems, Volume 189. Changes in the environmental impacts of pig production systems in Great Britain over the last 18 years – ScienceDirect
40. Fraanje, (2020). Soy in the UK: What are its uses? | TABLE Debates

41. Defra, (2022). Agri-climate report 2022 – GOV.UK (www.gov.uk)
42. Fraanje, (2020). Soy in the UK: What are its uses? | TABLE Debates
43. EFECA, The UK Roundtable on Sustainable Soya – Efeca
44. The UK Soy Manifesto. The Manifesto | The UK Soy Manifesto
45. Defra, (2022). Agriculture in the United Kingdom 2022, National statistics Chapter 7: Crops – GOV.UK (www.gov.uk)
46. Eory, V., MacLeod, M., Topp, C.F.E., Rees, R.M., Webb, J., McVittie, A., Wall, E., Borthwick, F., Watson, C., Waterhouse, A., Wiltshire, J., Bell, H., Moran, D., Dewhurst, R., (2015). Review and update the UK Agriculture Marginal Abatement Cost Curve to assess the greenhouse gas abatement potential for the 5th carbon budget period and to 2050. Microsoft Word – MACCUpdate2015_FinalReport-16Dec2015-Clear (theccc.org.uk)
47. NIAB, (2020). 23. Legume Crops for the UK 010620.pdf (niab.com)
48. NIAB, (2023). Legume Research at NIAB, page 6. 2023-Landmark-52-Spring.pdf (niab.com)
49. Defra, (2022). Agri-climate report 2022 – GOV.UK (www.gov.uk)
50. Beneficial effects of multi-species mixtures on N2O emissions from intensively managed grassland swards - ScienceDirect
51. Natural England, (2021). Carbon Storage and Sequestration by Habitat 2021 – NERR094 (naturalengland.org.uk)
52. Cantarello, E., Newton, A. & Hill, R., (2011). Potential Effects of Future Land-Use Change on Regional Carbon Stocks in the UK. Environmental Science and Policy. 14: 40–52.
53. Fornara, D. A., Wasson, E.-A., Christie, P. and Watson, C. J., (2016). Long-term nutrient fertilization and the carbon balance of permanent grassland: any evidence for sustainable intensification? Biogeosciences 13, 4975–4984 https://doi.org/10.5194/bg-13-4975-2016
54. Persson, T., Bergkvist, G. & Kätterer, T., (2008). Long-term effects of crop rotations with and without perennial leys on soil carbon stocks and grain yields of winter wheat. Nutrient Cycling in Agroecosystems 81(2), pp. 193–202.
55. Prade, T., Kätterer, T. & Björnsson, L., (2017). Including a one-year grass ley increases soil organic carbon and decreases greenhouse gas emissions from cereal-dominated rotations – A Swedish farm case study. Biosystems Engineering 164, pp. 200–212.
56. Blackwell, M.S.A., Takahashi, T., Cardenas, L.M. et al., (2024). Potential unintended consequences of agricultural land use change driven by dietary transitions. npj Sustain. Agric. 2, 1. https://doi.org/10.1038/s44264-023-00008-8
57. The Agroforestry Research Trust – Silvopasture
58. Woodland Trust (2022). Farming for the future: how agroforestry can deliver for nature and climate 2022 Report (woodlandtrust.org.uk)
59. Takahashi, T., Harris, P., Blackwell, M. S. A., Cardenas, L. M., Collins, A. L., Dungait, J. A. J., Hawkins, J. M. B., Misselbrook, T. H., McAuliffe, G. A., McFadzean, J. N., Murray, P. J., Orr, R. J., Rivero, M. J., Wu, L. and Lee, M. R. F., (2018). Roles of instrumented farm-scale trials in trade-off assessments of pasture-based ruminant production systems. Animal, Volume 12, Issue 8, 1766 – 1776. https://doi.org/10.1017/S1751731118000502
60. Windisch, W., (2022). The role of grassland and nutrient circularity in animal agriculture. International Meat summit: the Societal Role of Meat; TEAGASC, Dublin, Oct. 19–20, 2022.
61. van Selm, B., Frehner, A., de Boer, I.J.M. et al., (2022). Circularity in animal production requires a change in the EAT-Lancet diet in Europe. Nat Food 3, 66–73. https://doi.org/10.1038/s43016-021-00425-3
62. WRAP, (2016). Quantification of food surplus, waste, and related materials in the grocery supply chain. Technical report template WRAP waste Cymru
63. WRAP. The Courtauld Commitment 2030 | WRAP
64. Magistrali, A., Cooper, J., Franks, J., George, D. and Standen, J. (2021). Identifying and implementing regenerative agriculture practices in challenging environments: experiences of farmers in the north of England. PR640-09 Final report AHDB-BBSRC Farm Sustainability Fund (Cooper).pdf (windows.net)
65. AHDB, (2023). Case study: Putting a scientific spin on regenerative farming case study.pdf

66. Pasture for Life. The Pasture for Life Standards – Pasture for Life – Certified 100% grass-fed meat, milk, and dairy
67. Chatterton, J., Hess, T. and Williams, A., (2010). The Water Footprint of English Beef and Lamb Production – A report for EBLEX. 74310 – Water Footprinting English Beef and Lamb Final Report Sep 2010.pdf (windows.net)
68. Mekonnen, M.M., Hoekstra, A.Y., (2012). A Global Assessment of the Water Footprint of Farm Animal Products. Ecosystems 15, 401–415. https://doi.org/10.1007/s10021-011-9517-8
69. AHDB, (2019). Ammonia emissions on dairy farms https://ahdb.org.uk/knowledge-library/ammonia-emissions-on-dairy-farms
70. Defra, (2024). National statistics: Emissions of air pollutants in the UK – Ammonia (NH3) – GOV.UK (www.gov.uk)
71. AHDB, (2021). Trial saves pig industry an estimated £15.3m | AHDB
72. Defra, (2024). Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions – GOV.UK
73. Defra, (2023). Soil Nutrient Balances – GOV.UK
74. Dumont, B., Ryschawy, J., Duru, M., Benoit, M., Chatellier, V., Delaby, L., Donnars, C., Dupraz, P., Lemauviel-Lavenant, S., Méda, B., Vollet, D. and Sabatier, R., (2019). Review: Associations among goods, impacts and ecosystem services provided by livestock farming – PubMed (nih.gov), Animal, 2019 Aug, 13 (8): 1773–1784
75. Fraser, M.D., Vallin, H.E., Roberts, B.P., (2022). Animal board invited review: Grassland-based livestock farming and biodiversity, animal, Volume 16, Issue 12,2022. https://doi.org/10.1016/j.animal.2022.100671
76. Decaens, T., Jimenez, J.J., Gioia, C., Measey G.J. and Lavelle, P. (2006). The values of soil animals for conservation biology, European Journal of Soil Biology, 42 (Suppl. 1): S23-S38. https://doi:10.1016/j.ejsobi.2006.07.001
77. Meat in a Net Zero World
78. UK Cattle Sustainability Platform | British Meat https://sustainablebritishmeat.org/our-partners/uk-cattle-sustainability-platform/
79. FDTP: towards consistent, accurate and accessible environmental impact quantification for the agri-food industry - GOV.UK (www.gov.uk)
80. CIEL, (2023). Net Zero & Livestock: Bridging the Gap Report July 2023 | CIEL (cielivestock.co.uk)
81.. Decaens, T.; Jimenez, J. J.; Gioia, C.; Measey, G. J. & Lavelle, P. (2006). The values of soil animals for conservation biology. European Journal of Soil Biology 42 (Suppl. 1): S23-S38
82. FAO, (2023). Achieving SDG 2 without breaching the 1.5 °C threshold: A global roadmap, Part 1 – How agrifood systems transformation through accelerated climate actions will help achieving food security and nutrition, today and tomorrow. Rome. Achieving SDG 2 without breaching the 1.5 °C threshold: FAO's global roadmap
83. FAO, (2023). Pathways towards lower emissions – A global assessment of the greenhouse gas emissions and mitigation options from livestock agrifood systems. Rome. Pathways towards lower emissions (fao.org)
84. FAO. (2024). The State of Food and Agriculture 2024 – Value-driven transformation of agrifood systems. Rome.

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