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The effects of meat consumption on global health

A.M. Salter

Division of Nutritional Sciences, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leicestershire LE12 5RD, United Kingdom
E-mail: andrew.salter@nottingham.ac.uk

Summary
Meat represents an important source of high-quality dietary protein for a large proportion of the global population. In addition, red meat, in particular, significantly contributes to the intake of a wide range of micronutrients, including iron, zinc, selenium, vitamin D and vitamin B12. While these nutrients can be supplied in sufficient amounts by consumption of a range of fruit and vegetables, in many developing countries, where the availability of such foods may be limited, access to meat often protects against malnutrition and improves child cognitive development. Excessive consumption of meat and meat products is often associated with overconsumption of energy and fat, resulting in excess weight, obesity and an increased risk of chronic diseases, such as cardiovascular disease and type 2 diabetes. In addition, certain components of fresh and processed red meat may further increase the risk of these diseases and predispose the consumer to cancer, particularly colorectal cancer. In the face of population growth and global warming, there is increasing concern about the sustainability of farm animal production. Thus, while a modest intake of meat represents an important strategy to avoid essential nutrient deficiencies, limiting its intake can reduce the development of a range of chronic diseases and could have significant beneficial effects on global food security.

Keywords
Cancer – Cardiovascular disease – Diabetes – Environment – Health – Malnutrition – Meat.

Introduction: the contribution of meat to the human diet

While debate continues over the impact of carnivory on human development, there is irrefutable evidence that animal tissue became part of our diets very early in our history and probably at least 2 to 2.6 million years ago (1). One suggested impact of this is a marked reduction in the time to weaning and thus a reduction in the lactation and suckling periods, which has contributed to higher rates of reproduction and possibly increased brain mass and intelligence (2). While the origins of animal production for food may date back as far as 15,000 years, it was advances in our understanding of animal nutrition in the early 19th century which created a significant change in the availability of farmed meat and milk to large sections of the global population. Much of this innovation was driven from the rapidly industrialising 'Western world' and the increasing need to feed growing urban populations. However, it is undeniable that human beings are capable of not just surviving but maintaining long and healthy lives on diets free from animal products. Vegetarian or even vegan diets that are rich in a range of different fruit and vegetables can provide all of the energy, protein and micronutrients required to sustain life and maintain health (3).

Nonetheless, it is also clear that, for many, the lack of animal products in their diet is driven by necessity rather than choice, and many populations in the developing world are dependent on a very limited range of plant material, which leaves them vulnerable to protein-energy malnutrition and a wide range of micronutrient deficiencies. There is a long history of such countries becoming more economically stable and, as a result, large proportions of the population dramatically increasing their intakes of animal products (4).

Figure 1 illustrates the intake of different types of meat in different parts of the world. According to the Food and Agriculture Organization of the United Nations (5), the average per capita meat consumption in the world from 2014 to 2016 was 34.1 kg/per annum (pa) (retail weight equivalent). This consisted of approximately 60% red meat (beef, sheep and pork) and 40% white meat (poultry). North America continues to be the biggest consumer of

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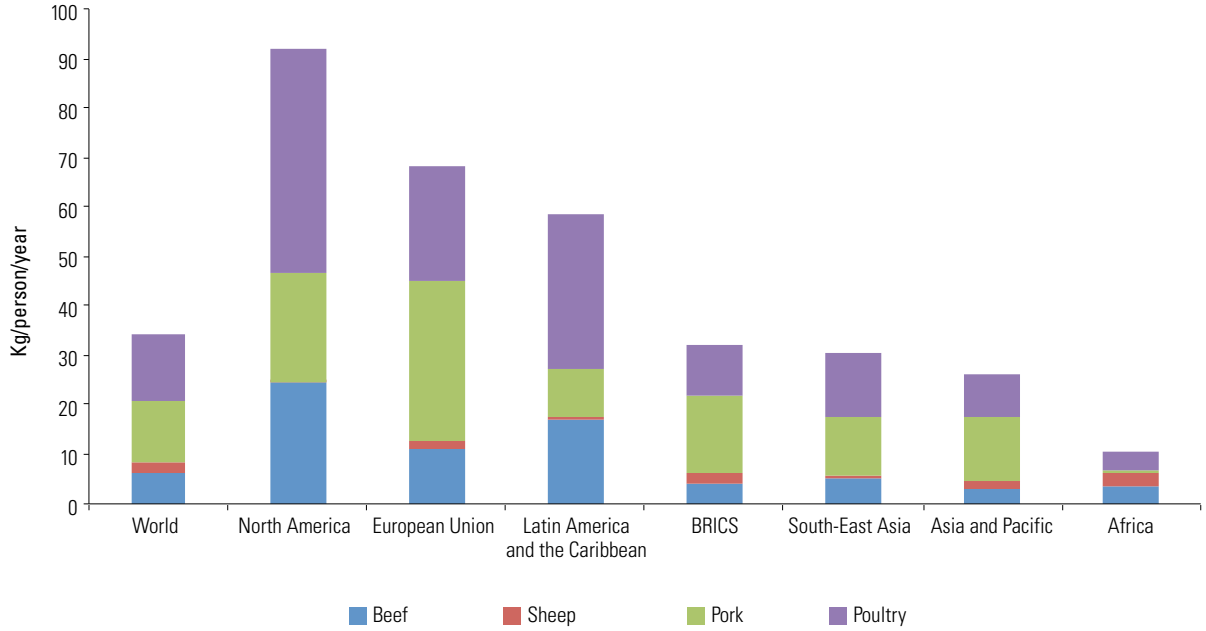

BRICS: Brazil, Russia, India, China and South Africa

Fig. 1
Estimated per capita meat consumption in selected regions (2014–2016)
Based on data presented by the Organisation for Economic Co-operation and Development and the Food and Agriculture Organization of the United Nations (5)

meat with an annual intake of 92.1 kg, which is split equally between red and white meat. By contrast, the average meat consumption in Africa was only 7.5% of this at 6.9 kg/pa (46% red and 54% white meat).

While such differences in intake are largely a result of economic inequalities, this also reflects marked differences in production efficiency. In the industrialised world, major advances in breeding, nutrition and husbandry practices have vastly increased efficiency and reduced the cost of animal production (4). This is particularly true of pig and chicken production, where a combination of genetic selection for lean tissue growth, coupled with the formulation of high-quality diets and improved husbandry techniques, has dramatically improved production efficiency. For example, compared to a historic strain of chickens which has remained unselected since 1957, a modern-day broiler strain has been shown to exhibit a 400% higher growth rate and to have a 50% lower feed conversion rate; that is, grams (g) of food consumed: g of body weight gained (6).

However, improvements are dependent on carefully controlled environmental conditions, with constant access to high-quality feed and water. Even such modern breeds of animal can fail to thrive when transferred to the more challenging environments often faced in developing countries. In many parts of the world, the efficiency of farm animal growth is further enhanced by the use of growth promoters, metabolic modifiers and anabolic agents (7). Recent advances in techniques for genetic manipulation (particularly in pigs) also suggest that this could be an affordable and effective way of further improving farm animal growth (8). While the potential further gains that could be achieved in conventional modern breeds may be relatively small, there is still considerable potential to improve the efficiency of breeds that are native to less developed parts of the world, since these are better adapted to the environmental conditions in which they are to be reared.

The environmental impact of livestock production

In recent years, much concern has been raised over the environmental impact of animal agriculture. In 2014, it was estimated that there were approximately 1.4 billion cattle, 1.9 billion sheep, 1 billion pigs and over 19 billion chickens on the planet (9). Monogastric species, such as chickens and pigs, are largely dependent on high-quality feeds, often derived from human-edible crops. While ruminant species (e.g. cattle and sheep) can be farmed on fresh or preserved plant material, not suitable for human consumption, in many parts of the world their diets are supplemented with cereal crops. Animal agriculture is also responsible for a significant proportion of human water use which is largely

used to irrigate feed crops (10). In addition, effluent from the livestock sector represents a major cause of freshwater pollution.

Livestock production has been estimated to contribute approximately 18% of greenhouse gas emissions, both directly (mainly methane production by ruminant species) and indirectly (largely due to deforestation associated with land-use changes for pasture and the production of feed crops) (10). It is inevitable that, with global population growth, increased economic stability in parts of the developing world and increasing human lifespan, the demand for meat will increase. Mitigation against the environmental impact of producing more farm animals represents a major challenge in the coming decades.

The contribution of meat to human nutrition

The nutritional value of meat varies considerably, depending on the species, strain and diet of the animal, the particular cut of meat and the method of cooking. Table I provides some examples of the major macronutrient content of some common, relatively lean cuts of grilled meat, compared to a variety of non-meat, plant-based staples. It is clear that, compared to carbohydrate-rich plant foods, all these meats are protein-rich. The red meats are also richer in total and saturated fats. By contrast, chicken is relatively low in fat. However, meat is not only rich in protein, but the protein is generally of higher quality (i.e. contains more essential amino acids) than plant equivalents. Perhaps unsurprisingly, as it comes from the muscle of other animals, it contains all the essential amino acids, in the appropriate proportions, to fulfil the nutritional requirements of humans.

Furthermore, when determining the quality of protein in a given food type, it is important to consider not only the amino acid content of the food but also the digestibility of the protein. Thus, when considering the value of a particular food in terms of protein, ideally the total amount of protein, essential amino acid content and overall digestibility should be considered. In general, meat (and other animal products, such as eggs and milk) scores highly on all counts and are assigned a protein–digestibility–corrected amino acid score (PDCAAS) of 100. Plant sources generally score lower, with potatoes, rice and wheat having scores of 82, 62 and 51, respectively (12). In both wheat and rice the essential amino acid, lysine, is the major limiting factor. Soya is widely regarded as one of the best plant sources of protein with a PDCAAS score of 90, which is why it is widely used as a major component of animal feed (12). Thus, when meat (or other animal products) is included in any quantity in the human diet, both total protein and amino acid requirements are comfortably met. For those who specifically avoid such products (or do not have access to them), then, unless they are consuming a range of different plant sources, deficiency can become a problem.

Table I
Macronutrient content of various meats compared to some plant-derived foods

	Energy	Protein	Fat	SFA	Carbohydrate
	MJ/100 g			g/100 g	
Beef	745	31.0	5.9	2.5	0
Lamb	1,268	26.5	22.1	10.5	0
Pork	1,074	29.0	15.7	5.6	0
Chicken	626	32.0	2.2	0.6	0
Bread	931	7.9	1.6	0.3	42.7
Potatoes	413	2.5	0.2	0.1	21.2
Rice	560	2.8	0.4	0.1	31.1

MJ: megajoules
SFA: saturated fatty acid
Figures are per 100 g serving of grilled meat (beef rump steak, lamb loin chop, pork loin chop or chicken breast), white bread, baked potato or boiled rice. Data taken from *McCance and Widdowson's composition of foods integrated data set* (11)

Meat also represents a valuable source of a wide range of essential micronutrients (13). Depending on the species, and diet on which they were fed, meat can make an important contribution to the intake of both omega-3 and omega-6 polyunsaturated fatty acids (PUFAs). In general, ruminant meats (beef and lamb) are poorer in these nutrients than meats from monogastric animals (chickens and pigs) (14). This is due to the inherently low fat intake of ruminant animals and the fact that much of the unsaturated fatty acids consumed by such animals is biohydrogenated by rumen microbes and converted into saturated fatty acids (SFAs). Considerable evidence exists to suggest that dietary intake of long-chain omega-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) is protective against a range of chronic diseases, including cardiovascular disease. While many populations obtain most of their dietary intake of such fatty acids from 'oily' marine fish, in the absence of this source, meat makes a significant contribution to intake and this can be further increased by the inclusion of such long-chain PUFAs in the diets of animals (particularly poultry) (15).

As can be seen in Figure 2, meat contributes a wide range of dietary minerals and vitamins. Perhaps the most important are iron, zinc and vitamin B12. While the entire contribution of meat to iron intake is approximately 21% of the total, it is important to recognise that iron associated with red meat (so-called 'haem iron') is considerably more bioavailable than the non-haem iron associated with plant sources. The proportion of haem iron absorbed may be two to three times that of non-haem iron (14). Iron deficiency represents one

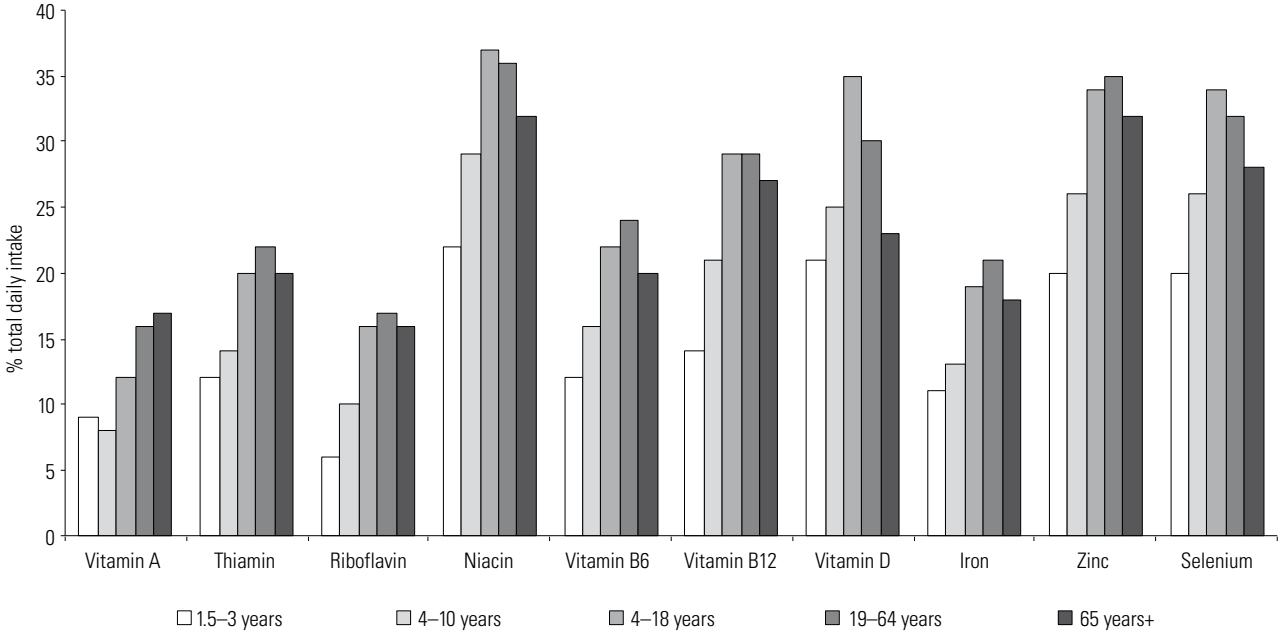

Fig. 2
Estimated contribution of meat and meat products to total intake of selected nutrients in the United Kingdom
Based on the national diet and nutrition survey 2008/2009 to 2011/2012 (16)

of the major nutritional problems across the world. Even in developed countries, intakes can often be below those recommended and this appears to be particularly prevalent in young females. Data from the United Kingdom (UK) suggest that 46% of girls between the ages of 11 and 18 have intakes below the lower reference nutrient intake (16). While zinc deficiency is less common than that of iron, the contribution of meat and meat products to daily intake is considerably higher, with UK adults obtaining 35% of their intake from these sources (16).

Meat, food security and malnutrition

For many in the developed world, meat is readily available and affordable, and represents a routine component of their diet. Equally, for those who choose to avoid meat, a large range of non-meat alternatives are available, from which it is relatively easy to select a diet of sufficient quantity and quality to maintain health.

However, in other parts of the world, particularly sub-Saharan Africa and the Indian subcontinent, large parts of the population live on the verge of malnutrition, with a very limited range of foods available to choose from. In such situations, rearing livestock for meat (together with milk, eggs and fish) on low-nutritional-quality plant materials often represents a vital way to generate highly nutritious components of the diet (17). Consumption of even relatively small amounts of meat and other animal products can have a major impact on preventing protein-energy malnutrition, iron deficiency anaemia and vitamin A deficiency, which represent major public health problems in such countries (17).

It is particularly important to recognise the impact of malnutrition and famine on the mental and physical development of children. A number of studies have highlighted the benefits, on both growth and cognitive development, of including meat and other animal products in the diets of children (18, 19, 20). The potential health benefits of consuming animal products have often been used to support the arguments for encouraging livestock rearing within family units in such poor communities. However, rather surprisingly, a recent study showed that household livestock ownership was only associated with a marginal improvement in stunting of children in three countries in eastern Africa (21). This highlights the complex interaction between livestock keeping and nutrition in such communities. For example, livestock may be sold rather than eaten, and the income generated may not necessarily be used to improve the diet of the most vulnerable in the family, who are often pregnant women and young children (22). Overall, it is clear that regular access to meat and other animal products has the potential to alleviate malnutrition. However, how to ensure such access for the most vulnerable within such populations requires further research.

Meat consumption and chronic disease

As described above, meat can make a valuable contribution to nutrient intake and may be particularly valuable when populations only have access to a limited range of fruit and vegetables. However, there has been increasing concern over the link between excessive meat intake and susceptibility to a range of chronic diseases, including cardiovascular disease (CVD), type 2 diabetes (T2D) and certain cancers, particularly colon cancer (15, 23, 24, 25). In general, these diseases appear to be specifically associated with red and processed meats, as opposed to fresh white meat. Processed meats are normally defined as those that have been preserved through treatments (curing, smoking, salting or the addition of chemical preservatives) other than freezing. A number of prospective cohort studies (mostly in Europe and the United States of America [USA]) have suggested a link between red and/or processed meat consumption and the risk of CVD. One of the largest of such studies was the combined analysis of the Nurses' Health Study and the Health Professionals' Study in the USA (26). These studies included a total of 121,322 individuals and recorded 5,910 deaths from CVD over a period between 1980 and 2008. One observation was that high meat consumption is associated with a range of other unhealthy lifestyle factors, including: excess weight and obesity, less exercise, more smoking and higher alcohol consumption.

However, even taking these factors into consideration, the greatest consumers of meat had a 40% increased risk of dying from CVD. This study also suggested that similar increases in risk were associated with both fresh and processed red meat. However, other studies have indicated that the consumption of processed meat carries a greater risk than fresh meat. For example, the European Prospective Investigation into Cancer and Nutrition (EPIC) study of 511,781 individuals, selected from ten European countries, suggested a significantly increased risk of CVD mortality associated with processed meat but not with either red or white fresh meat (27).

The mechanisms by which meat may contribute to an increased risk of CVD are yet to be fully elucidated. Diets rich in meat are often associated with a higher intake of SFAs. High SFA intake can increase plasma cholesterol, a known risk factor for increased risk of CVD. Many processed meats have a high salt content, which may contribute to elevated blood pressure, another potential risk factor. Red meat is rich in carnitine, which has been shown to be degraded to a chemical called trimethyl-amine-N-oxide (TMAO) by gut bacteria. In mice, a link has been suggested between increased TMAO levels and atherosclerosis, the underlying cause of CVD (28). However, such a link remains to be demonstrated in humans.

Over recent years, a number of epidemiological studies have demonstrated a link between red meat, and in particular processed red meat, and the risk of cancer. In reviewing the existing evidence, the International Agency for Research on Cancer (IARC) concluded in 2015 that processed meat is carcinogenic to humans and that fresh red meat is probably carcinogenic (29). The IARC Working Group based their findings on a review of over 800 epidemiological studies and concluded that, while the evidence was strongest for colorectal cancer, there was also evidence of a positive association between red meat consumption and pancreatic and prostate cancer and processed meat and stomach cancer. The mechanisms by which meat contributes to this increased cancer risk have largely been attributed to chemical carcinogens produced during curing or smoking of processed meats or through cooking meat at high temperatures (19).

A number of studies have reported a link between red and processed meat consumption and the risk of developing T2D. Type 2 diabetes is strongly associated with obesity and, as a high consumption of meat is frequently associated with energy-dense diets, often in combination with low physical activity levels, this may explain at least part of the association. Obesity frequently leads to resistance to the action of the hormone insulin and, in a proportion of obese people, this can develop further into T2D. However, it has also been suggested that specific components of meat, including branch-chain amino acids, advanced glycation end-products, haem iron, nitrates, nitrites and nitrosamine, phosphatidylcholine and L-carnitine, may all potentially affect glucose homeostasis and the risk of T2D (25). The possible mechanisms whereby such components may exert their effects remain largely a matter of speculation and further work is required to demonstrate direct links.

Conclusions

This review has attempted to demonstrate the balance between the health benefits of consuming meat and the potentially deleterious effects of overconsumption. Meat is clearly a source of high-quality protein and a range of micronutrients, including iron, which is often deficient across both the developing and developed world. While a meat-free diet can provide all of these nutrients, if one consumes a range of fruit and vegetables, deficiency becomes a problem in those on more restricted diets who are avoiding, or do not have access to, meat. In terms of the negative impacts of meat consumption, most of the available evidence suggests that white meat, derived from poultry, is a safe, low-fat source of high-quality protein. By contrast, commonly consumed red meats, including beef, lamb and pork, may impact on the risk of a range of chronic diseases if consumed in excess. Furthermore, processed red

meat may have the most deleterious effects; in particular by increasing the risk of colon cancer.

In light of this evidence, many countries have included limiting the dietary intake of fresh and processed red meat in their public health guidelines. For example, in the UK, the current recommendation is that adults restrict themselves to no more than one portion (70 g) of red and processed meat per day, in total (30). In addition to concerns about the effects of consuming large amounts of meat on public health, there is increasing recognition of the impact of animal agriculture on the environment. With a growing and aging population comes the increasing recognition that we should not only restrict our meat intake but also consider changes in animal production, including exploring the provision of more sustainable feed ingredients.

Les effets de la consommation de viande sur la santé dans le monde

A.M. Salter

Résumé

Pour une grande majorité de la population mondiale, la viande est une source importante de protéines de qualité. En particulier, la viande rouge contient divers micronutriments essentiels, dont le fer, le zinc, le sélénium, la vitamine D et la vitamine B12. Ces nutriments sont certes présents dans de nombreux fruits et légumes mais la disponibilité de ces aliments est souvent limitée dans les pays en développement, de sorte que c'est la consommation de viande qui permet de lutter contre la malnutrition et qui contribue au développement cognitif des enfants. D'un autre côté, une consommation excessive de viande et de produits carnés est fréquemment associée à une surconsommation de lipides et de protéines, avec pour effets une surcharge pondérale voire de l'obésité et un risque accru de maladies chroniques, dont les maladies cardiovasculaires et le diabète de type 2. En outre, certaines composantes de la viande rouge fraîche ou transformée majorent les risques associés à ces maladies ainsi que celui de développer un cancer, notamment colorectal. Compte tenu de la croissance de la population mondiale et du réchauffement climatique, la durabilité de la production animale est une question de plus en plus préoccupante. Par conséquent, si la consommation de viande en faibles quantités est une stratégie efficace pour lutter contre les carences en nutriments essentiels, le fait de limiter cette consommation permet de réduire l'exposition à plusieurs maladies chroniques et pourrait avoir un impact positif significatif sur la sécurité alimentaire à l'échelle mondiale.

Mots-clés

Cancer – Diabète – Environnement – Maladie cardiovasculaire – Malnutrition – Santé – Viande.

Efectos del consumo de carne en la salud mundial

A.M. Salter

Resumen

La carne constituye una importante fuente de proteínas alimentarias de gran calidad para una enorme proporción de la población mundial. Además, la carne roja, en particular, contribuye en gran medida a la adquisición de muy diversos micronutrientes, sobre todo hierro, zinc, selenio, vitamina D y vitamina B12 y, si bien es posible obtener estos nutrientes ingiriendo cantidades suficientes de diversas frutas y hortalizas, en muchos países en desarrollo, donde este tipo de alimentos a veces escasea, la posibilidad de consumir carne suele proteger de la malnutrición y mejorar el desarrollo cognitivo del niño. Un consumo excesivo de carne y productos cárnicos suele acarrear una aportación excesiva de energía y grasas, lo que se traduce en sobrepeso, obesidad y un mayor riesgo de enfermedades crónicas como las cardiovasculares o la diabetes de tipo 2. Además, ciertos componentes de la carne roja fresca o procesada pueden elevar el riesgo de padecer estas dolencias y predisponer al consumidor al cáncer, en particular el colorrectal. Ante el crecimiento demográfico y el calentamiento planetario, cada vez preocupa más la cuestión de la sostenibilidad de la producción de animales de granja. Así pues, a la vez que un consumo modesto de carne constituye un importante expediente para evitar carencias en nutrientes esenciales, el hecho de limitar la ingesta puede reducir la aparición de toda una serie de enfermedades crónicas y podría tener efectos muy positivos en la seguridad alimentaria mundial.

Palabras clave

Cáncer – Carne – Diabetes – Enfermedad cardiovascular – Malnutrición – Medio ambiente – Salud.

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