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Meat: The balance between nutrition and health. A review

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ABSTRACT

Fresh and processed meats provide high biological value proteins and important micronutrients. On the other hand, a working group of IARC recently classified processed meat as 'carcinogenic to humans' and red meat as 'probably carcinogenic to humans' for colorectal cancer, appealing to critically consider the future role of meat in a healthy diet. This manuscript first evaluates the contribution of meat consumption to the supply of important micronutrients in the human food chain, and the extent to which this can be improved by primary production strategies, and impacts on human health. Secondly, the IARC hazard analysis of the carcinogenicity of red and processed meat consumption is discussed, arguing that having more insight in the mechanisms of the association offers opportunities for mitigation. It is advocated that the benefits and risks associated with red and processed meat consumption should not necessarily cause dilemmas, if these meats are consumed in moderate amounts as part of balanced diets.

1. Introduction

Meat and meat products contribute significantly to the intake of energy, protein and important micronutrients, at least when consumed frequently (Givens, 2005; Givens, Kliem, & Gibbs, 2006; McAfee et al., 2010; Millward & Garnett, 2010). However, the consumption of animal-derived foods is highly variable among and within populations, hence the impact thereof on human health is also diverse (FAO, 2009). The global average meat consumption in 2005 was about 110 g per person per day, with a 10-fold variation between high-consuming and low-consuming populations (FAO, 2009). It is estimated that the demand for animal-derived foods and meat in particular in the coming decades will continue to grow strongly in developing countries, whereas in high income countries meat consumption may stagnate or even decline in future (FAO, 2009; Vranken, Avermaete, Petalios, & Mathijs, 2014). The current high levels of consumption of meat in many countries have been criticized for contributing to the burden of chronic diseases (World Cancer Research Fund / American Institute for Cancer Research, 2007), to competition between feed and food resources and to climate change and other environmental problems (FAO, 2009; Foley et al., 2011; Steinfeld, Gerber, Wassenaar, Castel, & de Haan, 2006). These issues apply more to 'red' meat and processed meat (mostly considered to be derived from mammals) than to 'white' meat (mostly derived from poultry), particularly with regard to human health considerations. The major difference between red and white meat refers to the higher myoglobin and heme iron content in red meat, but the definition of red and white meat is not always clear and can be debated (Demeyer, Mertens, De Smet, & Ulens, 2015). Anyhow, there is increasing evidence for a positive association between high red meat consumption, and even more processed meat but not white meat consumption, and several chronic diseases, among which colorectal cancer, coronary heart disease and type 2 diabetes (see Section 4).

For these environmental and health concerns, lowering the consumption of meat in general, but particularly red meat and even more processed meat, in high-consuming countries is now encouraged. This may pose nutritional challenges for some key nutrients in specific population groups, e.g. inadequate intake of vitamin B12, protein intake below requirements for the elderly, low Zn intake in relation to child growth (Millward & Garnett, 2010). It is clear that meat consumption is under transition and the future role of meat in society will be influenced by economic, environmental, ethical and health issues. However, since eating meat is a biocultural activity and has co-evolved with human development (Leroy & Praet, 2015), it elicits more than any other food strong emotional responses. This probably also explains why the debate on the nutritional benefits versus the possible adverse health effects of meat consumption is often polarized and irrational.

Whatever the future scenario of meat consumption will be, knowing the factors that determine the nutritional value of meat and the impact on human health and disease is important. The content of several micronutrients in meat is variable and amenable to manipulation, which may allow increasing or maintaining their supply in the food chain through meat consumption (De Smet, 2012; Givens & Gibbs, 2006, 2008; Rooke, Flockhart, & Sparks, 2010; Wood et al., 2008). Similarly, having more insight in the mechanisms of the association between red meat consumption and diseases offers opportunities for mitigation. The aim of this manuscript is first to evaluate the potential of primary

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production strategies to alter the contents of several micronutrients in meat for which average daily intake values are suboptimal in many countries (long chain n-3 PUFA, iron, zinc, selenium, iodine), and to critically review the impact of these improved meats on nutrient supply and health. The focus is on altering the composition of raw meat through the diet of animals, which has the advantage of increasing the flow of nutrients in the food chain on a population-wide scale. Secondly, the relationship between red and processed meat consumption and colorectal cancer risk will be briefly discussed in view of the recent evaluation by a working group of the International Agency for Research on Cancer (Bouvard et al., 2015).

2. Potential of improving the content of important micronutrients in meat

Apart from supplying high biological value proteins, meat is a valuable source of long chain n-3 fatty acids, essential trace elements (copper, iron, iodine, manganese, selenium, zinc), most B-vitamins, and a series of other micronutrients (Higgs, 2000; Henderson, Irving, & Gregory, 2003a; Williamson, Foster, Stanner, & Buttriss, 2005; Rooke et al., 2010). The content of micronutrients in meat depends on many factors and the potential to alter the composition of meat strongly differs according to the nutrient considered. Enhancing the content of long chain n-3 fatty acids in meat has been investigated extensively over the last decades. Less research has been devoted to trace elements in meat.

2.1. Essential fatty acid content of meat

A vast amount of research has been conducted in the last decades on the lipid and fatty acid metabolism in farm animals and the composition of their products. Whereas the amino acid profile of muscle tissue is relatively conserved, the fatty acid composition of animal products is more susceptible to manipulation. Animal fats strongly differ in fatty acid composition, but are generally considered too high in saturated and too low in polyunsaturated fatty acids (PUFA). On the other hand, apart from the major supply by fish consumption, meat and eggs are the only source of long chain n-3 PUFA for the majority of the population in many high-income countries that does not consume fatty fish on a regular basis (Gibbs, Rymer, & Givens, 2010). Moreover, meat is the main dietary source of docosapentaenoic acid (DPA, C22:5 n-3), which accumulates in meat from mammals and poultry, but not in fish, often at higher concentrations than both EPA and DHA (Dalziel, Kliem, & Givens, 2015; Howe, Meyer, Record, & Baghurst, 2006; Raes, De Smet, & Demeyer, 2004). Although there is little research on the clinical significance of DPA, it has been suggested to be inversely related to the risk of several chronic diseases and to be as beneficial, if not more, than EPA and DHA (McAfee et al., 2010). There are numerous studies and excellent reviews on the main factors determining the fatty acid composition of meat from different farm animal species. This information will not be repeated here. The effect of fat deposition in farm animals and the relationship between fat content and fatty acid composition in meat has been reviewed among others by De Smet, Raes, and Demeyer (2004) and Wood et al. (2008). The dietary fatty acid supply is the main factor governing the fatty acid composition of intramuscular fat and adipose tissue. This involves the source and content of dietary fat, and the duration and time of feeding. Effects of dietary strategies and fat sources have been discussed by Raes et al. (2004); Wood et al. (2003, 2008) and Nieto and Ros (2012) for various species, Scollan et al. (2001, 2006) and Lourenço, Van Ranst, Vlaeminck, De Smet, and Fievez (2008) for ruminants and Rymer and Givens (2005) for poultry. Collectively, this can be summarized as follows to our view.

- The fatty acid composition of adipose tissue and muscle in farm animals depends on the amount of fat in the carcass and in muscle. Effects of diet and genotype have therefore always to be interpreted against the amount of fat. To allow a proper evaluation of the impact on the human intake of fatty acids, fatty acid composition of meat should be reported on a tissue basis (mg/100 g sample weight) and not only as proportions of the total lipid fraction. In addition, it is highly recommended to take into account culinary practices, which may involve trimming of removable fat and often include a heat treatment and the use of culinary fats or oils, with significant effects on the fat content and the fatty acid profile of the meat as eaten (Haak, Sioen, Raes, Van Camp, & De Smet, 2007; Janiszewski et al., 2016).
- There are important differences among species that however can only be partly explained by differences in the digestive process. Because of the intense lipolysis and biohydrogenation taking place in the rumen, fats from ruminant animals are generally much higher in saturated fatty acids and lower in PUFA compared to fats from monogastric animals. There are also differences among species in the deposition of (long chain) PUFA in adipose tissue versus muscle. Ruminants deposit PUFA mainly in muscle whereas concentrations of PUFA are more similar for adipose tissue and muscle in pigs. Long chain (C20–22) PUFA are found in adipose tissue and muscle neutral lipids in pigs and sheep but much less so in cattle.
- In monogastric species, dietary fatty acids undergo little transformation during digestion and absorption. Hence, the fatty acid composition of tissues is a mirror of the dietary fatty acid composition in these species. On the other hand, products from ruminants do contain a series of minor fatty acids such as trans fatty acids, conjugated linoleic and α-linolenic fatty acids and odd and branched chain fatty acids, resulting mainly from rumen microbial biohydrogenation and metabolism. The beneficial or adverse human health effects of these minor fatty acids are still unclear and may differ for each of these specific fatty acids. Consequently, the effects of the regular intake of foods containing these fatty acids is not well established at present.
- The dietary supply of α-linolenic acid (ALA, C18:3 n-3) increases the content of ALA and total n-3 PUFA in muscle and adipose tissue. The increase in total n-3 PUFA mainly results from the increase in ALA and to a much lesser extent from increased concentrations of the long chain derivatives eicosapentaenoic acid (EPA, C20:5 n-3), DPA and docosahexaenoic acid (DHA, C22:6 n-3). Indeed, as in humans, the elongation and desaturation of ALA to long chain n-3 PUFA is limited in farm animals. Particularly the final synthesis of DHA is limiting, resulting mostly in no or a low increase in DHA content in meat from animals fed diets rich in ALA. Again, there are species differences with broilers being more efficient than other species in this respect (Poureslami, Raes, Turchini, Huyghebaert, & De Smet, 2010).
- A large increase in the content of long chain n-3 PUFA in meat requires the direct supply of these long chain n-3 PUFA by means of fish oil/meal or micro-algal oil/biomass incorporation in the diet. Due to declining fish oil supplies and increasing demands for long chain n-3 PUFA in the aquaculture industry, the use of micro-algae as the primary producers of long chain n-3 PUFA or other sources in future is a more desirable and sustainable strategy in the long term (Brunner, Sones, Friel, & Bartley, 2009; Givens & Gibbs, 2006). The deposition of DHA in tissues is as effective when using micro-algal biomass compared to fish oil (Rymer, Gibbs, & Givens, 2010, broilers; Vossen, Van Mullem, Raes, & De Smet, 2009, pigs). An alternative strategy that has been investigated to increase the long chain n-3 PUFA content in animal tissues is the use of oils from plants high in stearidonic acid (C18:4n-3), such as primrose, echium and hempseed (Lenihan-Geels, Bishop, & Ferguson, 2013) or from transgenic soyabeans (Rymer, Hartnell, & Givens, 2011). The rationale of this approach is to bypass the rate limiting enzyme, Δ6-desaturase, as stearidonic acid is the first desaturation product in the conversion of ALA to its long-chain derivatives. However, no advantage of echium oil over linseed oil was found in lambs (Kitessa et al., 2012) and in pigs (Tanghe, Millet, & De Smet, 2013), and similarly no advantage of transgenic soyabeans was noted in poultry (Rymer et al., 2011). A