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Review article

Dietary sources of unsaturated fatty acids for animals and their transfer into meat, milk and eggs: A review

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ABSTRACT

Dietary intake of unsaturated fatty acids (UFA) has been shown to reduce the risk of cardiovascular disease (CVD) and possibly the incidence of some cancers, asthma and diabetes among other conditions. Meanwhile, animal products have been criticised for their high content of saturated fatty acids (SFA), being damaging to health. Modification of animal diets can now easily increase the proportion of UFA in meat, milk and eggs. Consuming a greater proportion of these beneficial fatty acids as part of an everyday diet will appeal to the public, as opposed to taking dietary supplements. This study encompasses a review of the literature on dietary sources of UFA available for animals and their subsequent transfer into milk, meat (beef, lamb, pork, poultry) and eggs. Including these fatty acid sources in the diet of animals improves the fatty acid profile of milk, meat and eggs by increasing the ratio of UFA:SFA, decreasing the ratio of *n*−6:*n*−3 fatty acids and, with ruminant products, increasing conjugated linoleic acid (CLA) levels. Care must be taken however, when introducing these fatty acid sources into animal diets as some adverse effects can result. For example, large amounts of UFA in the diet of dairy cows may affect rumen activity, reducing milk yield, fat and protein concentrations, while the impact of increased levels of polyunsaturated fatty acids (PUFA) in meat on shelf life and flavour parameters is an area that warrants further investigation. Novel fatty acid sources such as hemp, camelina or lupin, although effective in some instances, are so far proving an expensive option for commercial purposes. Current thinking on the relevance of the dietary *n*−6:*n*−3 ratio to cardiovascular risk in humans is also examined.

Contents

Abbreviations: ALA, Alpha linolenic acid; BSAS, British Society of Animal Science; BW $^{0.75}$, Metabolic body weight; *c*, *cis*; CLA, Conjugated linoleic acid; CVD, Cardiovascular disease; DEFRA, Department for Environment, Food and Rural Affairs; DHA, Docosahexaenoic acid; DM, Dry matter; DPA, Docosapentaenoic acid; EPA, Eicosapentaenoic acid; GB, Great Britain; GHG, Greenhouse gas; LA, Linoleic acid; LCPUFA, Long chain polyunsaturated fatty acids; MAFF, Ministry of Agriculture, Fisheries and Food; MAP, Modified atmosphere packaging; MUFA, Monounsaturated fatty acids; NDNS, National Diet and Nutrition Survey; *n*, Omega; PCD, *Pars costalis diaphragmatis*; PLS, Protected linseed and soyabean supplement; PUFA, Polyunsaturated fatty acids; ROS, Reactive oxygen species; SACN/COT, Scientific Advisory Committee on Nutrition/Committee on Toxicity; SFA, Saturated fatty acids; Total FA, Total fatty acids; *t*, *trans*; UFA, Unsaturated fatty acids; USITC, US International Trade Commission; VA, Vaccenic acid; VLDLP, Very low density lipoprotein; WHC, Water holding capacity; WHO, World Health Organisation.

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1. Introduction

Meat and milk consumption is predicted to increase globally over the next twenty years in line with an increasing world population, a greater income potential and the availability of these foods to meet human nutrient requirements as part of an everyday diet (World Health Organisation, 2003). In the most recent Great Britain (GB) National Diet and Nutrition Survey (NDNS), meat and meat products and milk and milk products were found to supply 25% of total dietary energy intake (Henderson et al., 2003). Together, they also contributed almost half of the saturated fatty acid (SFA) intake, while meat and meat products were the largest provider of monounsaturated fatty acids (MUFA) and similar to the cereal groups as suppliers of both omega-3 ($n-3$) and omega-6 ($n-6$) polyunsaturated fatty acids (PUFA). Milk and milk products and ruminant meat and meat products were also significant sources of *trans* (t) fatty acids. Givens and Gibbs (2006), in a detailed review of the role of meat as a source of $n-3$ PUFA in the human diet, considered that the contribution of meat to dietary intake of these beneficial fatty acids could be increased by enriching the animal diet.

The current review examines the sources of fatty acids available for inclusion in animal diets and their subsequent transfer into meat, eggs or milk for human consumption.

1.1. Fatty acids commonly found in milk, meat and eggs

The principle fatty acids commonly found in milk and dairy products, beef, lamb, pork, poultry and eggs under standard production systems are summarised in Table 1. These will have been influenced by the composition of the diet, the digestive system of the animal and by the biosynthetic processes within the animal. Only the major fatty acids are listed in Table 1, and in ruminant products in particular, there are many other minor fatty acids including branched and odd-numbered fatty acids, as well as intermediate products of ruminal biohydrogenation. Some of these fatty acids, although present in relatively small amounts, have been reported to have high levels of biological activity, for example, conjugated linoleic acid (CLA) and its isomers (Bhattacharya et al., 2006).

1.1.1. Lipid digestion in ruminants and non-ruminants

The nature of lipid digestion by the animal (ruminant or non-ruminant) has a substantial effect on the transfer of fatty acids from the diet into the animal product. The principal site of digestion of dietary lipid in non-ruminant animals is the small intestine. Pancreatic lipase breaks the triacylglycerols down to mainly 2-monoacylglycerols and free fatty acids and the formation of micelles aids absorption, with lipid uptake mediated by the lipoprotein lipase enzyme, which is widely distributed throughout the body. Unlike the ruminant, dietary fatty acids in the non-ruminant are absorbed unchanged before incorporation into the tissue lipids. Dietary lipid sources therefore have a direct and generally predictable effect on the fatty acid composition of pig and poultry products (Chesworth et al., 1998) and the supply of unsaturated fatty acids (UFA) to tissues may be simply increased by increasing their proportion in the diet.

In contrast, the rumen microorganisms in the ruminant digestive system have a major impact on the composition of