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Nutritional strategies to improve the lipid composition of meat, with emphasis on Thailand and Asia

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ABSTRACT

This article reviews opportunities for enriching the lipids of meat with $n-3$ fatty acids and conjugated linoleic acids (CLAs), both considered beneficial to human health. Special focus is put on feeds available and research carried out in Thailand. A differentiated consideration concerning the value of different $n-3$ fatty acids and isomers of CLAs is necessary. In ruminants, it is difficult to enrich the meat with $n-3$ fatty acids due to the extensive ruminal biohydrogenation of unsaturated fatty acids, but several possibilities to enhance the proportion of the most desired CLA isomer, rumenic acid, exist. By contrast, pork and poultry meat can be easily enriched with $n-3$ fatty acids. With purified CLA sources, CLAs also can be enhanced, but it is difficult to achieve this exclusively for rumenic acid. An interesting approach might consist in supplementing the CLA precursor vaccenic acid instead. Possible constraints for meat quality and in the fatty acid levels achieved are outlined.

1. Introduction

1.1. Meat consumption in Thailand

Trends in production and consumption of meat in 'transition' countries are rapidly changing. Countries as a whole have been decisively influenced not only by China's rapid growth in meat consumption in the last two decades, but also by a similar development in Brazil (from 32 kg in the mid-1970s to 71 kg at present) (FAO, 2015). Including these two countries, the per capita meat consumption in developing countries increased from 11.4 to 25.5 kg in the last two decades. Excluding them, it increased from 11 kg to only 15.5 kg (FAO, 2015). Similar trends as in China and Brazil are currently ongoing in Thailand. Export of meat (million tons in 2015) from Thailand by far exceeds import in pork (export: 17; import: 2) and poultry meat (export: 622; import: 4), whereas no significant export of beef takes place (Office of Agriculture Economics, 2015). This illustrates that the quality Thai pork and poultry meat has an international relevance as well. With this substantial growth in the demand for high quality protein, in conjunction with a growing world population, the meat sector faces a promising though challenging future. New scientific knowledge and technology are very important to profit from this great opportunity. Efficiency at all levels from breeding and farming to processing and dispatch is crucial for success and there is still a large potential for efficiency increases (Kristensen, Støier, Würtz, & Hinrichsen, 2014). An increasing awareness of sustainability of meat production will lead to changes going beyond the efficiency goal and thus producers will have to respond to major challenges in feed availability, animal welfare and biodiversity. In addition, consumers demand appealing but, at the same time, safe and nutritious foods which are free of synthetic preservatives or other food additives. Nutritional quality is increasingly an

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important deliberation in food choices made by consumer as a consequence of the growing awareness of the importance of the implications for human health. For instance, Morales, Aguiar, Subiabre, and Realini (2013) showed that health reasons are one of the relevant factors affecting consumers' purchase of certified beef products. Transition countries like Thailand are currently experiencing increasing rates of certain diseases as they proceed with their socioeconomic development. Consistent with this, cardiovascular disease (CVD) has been the second most prevalent cause of death since 2000 in Thailand after carcinoma, and approximately four Thai inhabitants die per hour from CVD (MOPH, 2015). Among many other reasons, this is also likely a consequence of a significant diet change, with meat forming an increasingly important component.

1.2. Health aspects of lipids in human diets

Dietary fat impacts, both positively and negatively, human health. In general, foods with low fat content or a high proportion of unsaturated fatty acids are aimed at. For several decades, dietary guidelines have recommended avoiding high intake of saturated fat in order to prevent CVD (Krauss et al., 2000). More specifically, the beneficial influence of polyunsaturated fatty acids (PUFAs), especially the $n-3$ fatty acids, on human health is acknowledged. Similarly, a focus is put on conjugated linoleic fatty acid (CLA), as a higher content of CLA, a higher CLA proportion in the lipids of food a and a lower $n-6$ polyunsaturated fatty acid/$n-3$ polyunsaturated fatty acid ratio have been shown to be beneficial to human health (Liu & Ma, 2014). Red meat, in particular, is also an important source of micronutrients with presumed anticarcinogenic properties apart from $n-3$ fatty acids and CLA, namely selenium, vitamin B_6 and B_{12}, and vitamin D (Ferguson, 2010). These constituents are often referred to as 'bioactive' or 'functional food' components which also can play an important role in health maintenance and the prevention of chronic diseases. In the present review, however, we focused on meat enriched with functional fatty acids ($n-3$ and CLA) considered beneficial for human health. The major focus of this review is on nutritional rather than genetic approaches since the latter has less impact on fatty acid composition compared to that on the amount of fat. As a general rule, genotypes less intensively selected for growth performance, which are prevalent in Thailand, provide meat with higher content of fat, and fat stores are richer in saturated fatty acids than functional lipids, which are at higher proportions in lean tissue (Kreuzer, Gerdemann, & Reyer, 1997). Focus was also not put on known influences of other production system factors on the fatty acid profile of the meat (Wood et al., 2004).

1.2.1. $n-3$ fatty acids

The beneficial influence of the $n-3$ fatty acids has been extensively explored since the 1970s when expeditions revealed that Greenland Eskimos had an extremely low incidence of CVD, though their traditional diet was rich in fat, saturated fatty acids (SFAs) and cholesterol (Wood et al., 2008). Since this discovery, it has been shown repeatedly that the $n-3$ fatty acids can help prevent the development of CVD and inflammatory pathologies (Bou, Codony, Tres, Decker, & Guardiola, 2009; Calder & Yaqoob, 2009).

Especially eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA) are presumed to be beneficial over other $n-3$ fatty acids including α-linolenic acid (ALA) for the maintenance of long term health (McAfee et al., 2010; Simopoulos, 2002) and brain development in children (Innis (2007). The $n-3$ PUFAs in general have been reported to have the potential to reduce risk of CVD, Alzheimer disease, atherosclerosis, obesity, type II diabetes, osteoporosis, dry eye syndrome (McAfee et al., 2010; Molendi-Coste, Legry, & Leclercq, 2011), and psoriasis (Zulfakar, Edwards, & Heard, 2007). They have also been used in the treatment and prevention of depression in adolescents with eating disorders (Swenne, Rosling, Tengblad, & Vessby, 2011). The $n-3$ fatty acids also help the brain to repair damage by promoting neuronal growth (Kockmann, Spielmann, Traitler, & Lagarde, 1989). In a 6-month study involving people with schizophrenia and Huntington's disease, a placebo group had clearly lost cerebral tissue, while the patients given EPA exhibited a significant increase of gray and white matter (Petrik, McEntee, Johnson, Obukowicz, & Whelan, 2000).

There are several, sometimes different, recommendations for daily intake of humans of PUFAs, especially $n-3$ PUFA (Table 1). In comparison, the amounts of $n-3$ PUFA consumed with the average human diet in Western countries are only about 0.15 g/day, i.e., far below the recommended levels (Kolanowski & Laufenberg, 2006). Another approach for a recommendation is through the $n-6$:$n-3$ ratio, which should be less than either 4:1 (Simopoulos, 2002) or 5:1 (DACH, 2000) which is hard to achieve without significant amounts of fish oils (Aleksandra et al., 2009). Indeed, this ratio is often higher than 4:1 in meat. It is known to be of nutritional importance as it is the key index for balanced synthesis of eicosanoids in the body (Abedi & Sahari, 2014), but is currently less frequently used.

1.2.2. Conjugated linoleic acid

Conjugated linoleic acid comprises a group of geometric and positional isomers of linoleic acid with double bonds not separated by a CH_2 group. A generalization of CLA effects in relation to the prediction of the benefit for human health is prohibitive as it includes clearly favorable isomers like C18:2 *cis*-9, *trans*-11 (rumenic acid; RA) (Niwinska, 2010) but also less desired isomers like the C18:2 *trans*-10, *cis*-12 (Tous et al., 2013). The latter is mostly a product from industrial hydrogenation of PUFA, and thus part of diets for livestock when feeding hydrogenated fats or pure CLA (Schmid, Collomb, Sieber, & Bee, 2006). Commercial pure CLA is typically a 1:1 mixture of RA and C18:2 *trans*-10, *cis*-12.

In general, CLAs have been linked to a range of health benefits based on results of *in vitro* and animal studies. However, because of the current lack of dietary intervention or cohort studies showing significant benefits of CLA in man, there are no accepted dietary guidelines for CLA intake yet (Bhattacharya, Banu, Rahman, Causey, & Fernandes, 2006). In general, CLAs were linked to a reduced risk of CVD and certain types of cancers. In addition to this, CLA may have anti-atherosclerotic, antioxidant, and immunomodulatory properties (Azain, 2003). The CLA may also play a role in the control of obesity (Park, Albright, Storkson, Liu, & Pariza, 2007), reduction of the risk of diabetes (Hamura, Yamatoya,

Table 1
Selection of recommended dietary intakes of key polyunsaturated fatty acids (PUFA).

Recommendations	% of energy	mg/day	Reference
Linoleic acid	4	–	NDA (2010)
α-linolenic acid	0.5	–	NDA (2010)
		1100/1600[a]	Institute of Medicine of the National Academies (2005)
Eicosapentaenoic acid (EPA)	0.05	100-120	Astorg et al. (2004)
Docosahexaenoic acid (DHA)	–	200	Koletzko et al. (2008)
EPA + DHA	–	250	NDA (2010)
$n-3$ long-chain PUFA	–	250	Abedi and Sahari (2014)

[a] First value for women, second for men.