Influence of dietary rape seed oil, vitamin E and $CuSO_4$ on quality of raw and processed pork meat products during storage

Claus Jensen, Leif H. Skibsted & Grete Bertelsen

Department of Dairy and Food Science, The Royal Veterinary and Agricultural University, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark, E-mail ls@kvl.dk.

Background Contemporary human health guidelines recommend increasing the intake of unsaturated fatty acids on the expense of the saturated fatty acids. Diets rich in oleic acid have been shown to reduce the oxidative modification of high-density proteins in man[1], and thus increasing the amount of oleic acid in the fat tissue of pigs is suggested to improve the nutritional value of pork meat. Pigs are able to incorporate dietary fatty acids directly into adipose and muscle tissue lipids, making it possible to modify the fatty acid composition of pigs by the strategic use of unsaturated dietary fat sources[2].

Rape seed oil is highly unsaturated and has therefore considerable potential as a source of unsaturated fat for pig meat production. However, dietary rape seed oil treatments tends to increase the susceptibility of muscle tissue towards oxidation[3], apparently, due to the high level of polyunsaturated fatty acids in the rape seed oil.

Prevention of lipid oxidation in muscle-based food can be achieved by the addition of synthetic antioxidants *e.g.* BHT, BHA or TBHQ. However, consumer concerns about the use of synthetically chemicals in foods have increased the interest for usage of natural antioxidants for food formulation *e.g.* spice extracts, vitamin E and C[4,5]. Another approach for controlling lipid oxidation in muscle-based food is to improve the antioxidant systems naturally occurring in muscle tissues. In relation to muscle-based food, the influence of endogenous vitamin E has received most interest and incorporation of higher levels of vitamin E in pig tissues by dietary supplementation has been shown to be an efficient method to improve oxidative stability of pig meat lipids[6,7]. Dietary vitamin E has further been found to decrease drip loss[8] and to improve colour stability of raw chill-stored pork chops[9].

The use of $CuSO_4$ as a growth promoter in pig production has lead to concerns about the effect of copper on the quality of meat and meat products. One concern has been that addition of copper to diets at a level sufficient to promote growth produces soft fat, caused by copper activation of the desaturase enzymes of the triglycerides[10]. Another concern has been, if the high levels of dietary copper increases amounts of "free" copper in the pork tissues and thereby directly may influence oxidative stability of the meat negatively.

Objective A joint European research programme (Diet-Ox) with 14 partners was formed with the objective to develop a better scientific understanding of the effects of dietary modification on the physiological status of animals and on the production of muscle foods with optimum oxidative stability, shelf-life, colour, flavour, wholesomeness and nutritive value. Danish Landrace x Danish Yorkshire female pigs were fed either a standard diet or standard diet enriched with 6% rape seed oil supplemented with increasing amounts of vitamin E (0, 100 or 200 mg *all-rac*-α-tocopheryl acetate/kg) and copper (0, 35 or 175 mg $CuSO_4$/kg), and the following effects and pork product types were studied:

The effect of dietary rape seed oil, vitamin E and $CuSO_4$ on the quality of raw pork chops (oxidative stability, colour, drip loss) packed in atmospheric air or in modified atmosphere with a high oxygen content[11].

The effect of dietary rape seed oil, vitamin E and $CuSO_4$ on the quality (oxidative stability, colour, drip loss) of chill-stored, pre-frozen pork chops packed in atmospheric air [12].

The effect of dietary rape seed oil, vitamin E and $CuSO_4$ on the oxidative stability of frozen-stored, vacuum-packed, pre-cooked sausages[12].

The effect of dietary rape seed oil and vitamin E on the oxidative stability and development of warmed-over flavour in chill-stored pre-cooked pork patties[13].

Materials and methods Rearing and slaughtering is described by Lauridsen *et al*[14]. The studies of the effects on meat quality of various pork meat products have been described by Jensen *et al.*[11-13].

Results and discussion Levels of vitamin E in muscles and products were found to be closely correlated to the level of dietary supplementation. The increased levels of vitamin E in the pork meat products significantly depressed lipid oxidation in the products. The natural content of vitamin E originating from the rape seed oil was found to have a marked influence on the total amount of vitamin E found in muscles and in products. In our studies, the extra vitamin E originating from the rape seed oil was found to significantly improve the oxidative stability of the pork products from pigs fed non-vitamin E supplemented diets.

Endogenous vitamin E levels only to a small degree influenced the surface colour of fresh chill-stored pork chops and vitamin E was not found to affect the degree of drip loss in raw chill stored or in pre-frozen chill stored pork chops[11].

The stability of the vitamin E in raw meat was high, but freezing, prolonged storage, heating and mincing resulted in some vitamin loss. Despite the degradation the significantly improved oxidative stability of products (obtained by feeding pigs supra-nutritional levels of vitamin E) was still evident in the processed and stored products[12,13] .

Lipid oxidation in raw pork chops is of minor importance, but packing in modified atmosphere with high levels of oxygen was found to accelerate oxidation processes, resulting in quality deterioration[11]. However, increasing vitamin E levels of the raw meat by supra-nutritional feeding was proven to be an effective approach to offset the increased lipid oxidation in pork chops packed in high oxygen atmospheres[11].

Lipid oxidation in cooked pork products during chilled or frozen storage was markedly increased, compared to the raw unprocessed meat, and lipid oxidation can be considered to be the main factor determining the quality and shelf-life of these products.

The presence of increased vitamin E levels in the raw meat was shown to significantly decrease lipid oxidation in cooked, chilled and frozen stored pork products[12,13]. The effect of vitamin E supplementation was evident even when cooked products were vacuum-packed. The quality of pork meat and pork meat products was found to be unaffected by the addition of the growth promoter $CuSO_4$ to pig diets[11,12]. Addition of rape seed oil to pig diets was found to decrease the oxidative stability of chill-stored, cooked, lean patties and of frozen stored, high-fat cooked sausages, whereas the oxidative stability of raw, lean pork meat was unaffected. The detrimental effect of rape seed oil on lipid oxidation was only evident in products with low levels of vitamin E. The addition of rape seed oil to pig diets increased dietary vitamin E levels, due to the natural vitamin E inherent in the oil. This resulted in significantly increased muscle and product levels of vitamin E. Hence, the unchanged oxidative stability of raw, lean pork meat may partly be attributed to the vitamin E originating from the rape seed oil. Feeding pigs supra-nutritional levels of vitamin E effectively neutralised the effect of rape seed oil, and provided an effective protection against lipid oxidation[11,12,13].

The effect of the intake of pork fat and meat with an improved nutritional fatty acid profile on plasma cholesterol concentration in humans, using the animals from the presented feeding experiment, was investigated by Sandström *et al.*[15].

Conclusion Feeding pigs supra-nutritional levels of vitamin E improves the oxidative stability of the *post-mortem* meat by increasing the amount of the lipid-soluble antioxidant incorporated into the meat. In other words, the raw-material used for production of pork meat and meat products are improved. This improved built-in protection against lipid oxidation was found to be manifested in all pork products where lipid oxidation was of a significant magnitude, and the effect became more evident as the oxidative stress increased. Lipid oxidation in processed products is markedly increased compared to raw meat and for the production of products the use of a raw-material with increased oxidative stability is highly recommendable.

An increase in the amount of polyunsaturated fatty acids in pig fat may decrease the oxidative stability pork of meat products, but the effect can be effectively neutralised by a concurrent supplementation of pigs with supra-nutritional levels of vitamin E. Hence, it is possible to produce pork meat with an improved nutritional value with increased amounts of mono- and polyunsaturated fatty acids without adversely changing the oxidative stability of the pork products. Compared to the influence on lipid oxidation, the effect of dietary vitamin E supplementation on colour and drip loss seems to be of minor practical importance.

Controlling lipid oxidation is a multi-factorial process including many control points, beginning with the endogenous level of vitamin E of the raw-material. In conclusion, a large variety of products are produced from the pig carcass, of which all will benefit from being produced from a high-quality raw-material with an optimum inherent protection against lipid oxidation, achieved by supplementing pig diets with supra-nutritional levels of vitamin E.

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