Impact of Dietary Selenium on Meat Quality

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Introduction

There are a number of meat quality characteristics that are favored by consumers and influence the eating quality of meat. These characteristics include appearance, color, tenderness, texture, flavor and aroma (Buckley *et al.*, 1995; Liu *et al.*, 1995). Color and oxidative stability of the meat are influential in the purchasing decision process at the supermarket or point of sale (Sheehy *et al.*, 1997). Consumers are not willing to accept meat products that have unwanted characteristics and therefore it is important for food packers and processors to control lipid oxidation, avoid discolorations, and preserve meat quality as such.

Oxidation of muscle lipids after slaughter can negatively affect flavor and nutritive values of meat and meat products (Morrissey *et al.*, 1998) and limits their acceptability (Gray *et al.*, 1996). Oxidation affects lipids, pigments, carbohydrates, proteins, and vitamins. Oxidation causes discoloration, drip losses, off-flavor development, loss of nutrient value, and the production of toxic or potentially toxic products (Benzie 1996).

The susceptibility of meat and meat products to oxidation depends on a number of factors including the level of polyunsaturated fatty acids present in meat tissues (Robey and Shermer 1994), the presence of low molecular weight metals and iron-containing heme proteins. During processing and or cooking, the disruption of lipid membranes facilitates the interaction of prooxidant molecules (oxygen and low molecular weight metals -iron and copper), with unsaturated fatty acid resulting in the generation of free radicals and propagation of oxidative reactions (Asghar *et al.*, 1988) that leads to off-flavors, off- colors, and poor texture (Stanley, 1991).

The use of antioxidant systems have been suggested in order to maximize oxidative stability along the food chain, starting typically at the first link: the farm (Decker, 1998; Valenzuela, *et al.*, 2004). Our objective for this paper is to provide a brief summary of what can be done at the production level through dietary modification and offer some insight into the opportunities that the essential trace mineral selenium can offer to the meat industry regarding meat quality.

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Proceedings of the 57th American Meat Science Association Reciprocal Meat Conference *(pp. 19-23)*
June 20-23, 2004, Lexington, Kentucky
www.meatscience.org

Feeding Strategies

The dietary regimen of the animal is important since it influences meat flavor and lipid oxidation (Gray *et al.*, 1994; O'Sullivan *et al.*, 2002). A review of studies on forage finishing showed mixed results (O'Sullivan *et al.*, 2002). Palatability characteristics, tenderness, juiciness, and flavor were not different between forage and grain fed heifers and beef. (Crouse *et al.*, 1984; Fortin *et al.*, 1985). However grass feeding produced beef darker in color during retail display when compared to grain (Crouse *et al.*, 1984). Smith (1990) favored grain finishing over forage finishing of beef since this latter showed lower dressing percentage, decreased quality grade, yellow fat color, dark muscle color, and decreased flavor and tenderness. O'Sullivan *et al.*, (2002) reported that beef from animals fed grass silage had better overall quality in terms of color and lipid oxidation than beef from animals fed maize silage and indicated animals fed maize silage had the highest color and lipid deterioration compared to grass silage fed animals. Most likely the differences in results could be attributed to differences in vitamin E content of the diets. O'Sullivan *et al.*, (2002) indicated that the grass silage group which had the greatest color stability had the highest level of α-tocopherol compared to the maize treatment, which is in agreement with previous findings (Kerry *et al.*, 2000). Turner *et al.*, (2002) observed that lambs finished on concentrates with supplemental vitamin E prior to slaughter showed less lean discoloration during display case storage.

The Role of Selenium and Vitamin E

The role of Vitamin E to quench free radicals is fairly established and has been reviewed in detail elsewhere (Surai, 2002). It has been demonstrated that vitamin E supplementation of meat-producing animals increases muscle α-tocopherol concentrations (Arnold *et al.*, 1992; Monahan *et al.*, 1992; Guidera *et al.*, 1997ab; Lauridsen *et al.*, 1997; Mitsumoto *et al.*, 1998), effectively extending color and lipid stability in displayed fresh meat for several days (Faustman *et al.*, 1989a,b; Arnold *et al.*, 1992).

The improvements in color stability have been associated to an α-tocopherol mediated mechanism to reduce lipid and myoglobin oxidation (Faustman *et al.*, 1989b). Myoglobin oxidation (conversion to metmyoglobin) was slower in semimembranous cuts stored for six days from lambs supplemented with 1,000 IU of vitamin E/kg DM when compared to lambs supplemented with 20 IU /Kg DM (Guidera *et al.*, 1997). This effectiveness has been attributed to vitamin E's role in protecting oxymyoglobin from the effects of oxidizing lipids (Yin and Faustman, 1994; O'Grady *et al.*, 1996).

Selenium was shown to be an essential trace mineral for mammals in the late 50's (Scharwz and Foltz, 1957). Rotruck *et al.*, (1973) showed that selenium is an integral part of glutathione peroxidase (GSH-Px), an enzyme involved in detoxification of hydrogen peroxide and lipid hydroperoxides, preventing oxidative damage to body tissues. Most of the work since then has focused on the role of selenium and its impact on animal health and production responses.

A number of studies have shown a dietary Se supplementation response in poultry (Cantor and Scott, 1974; Moksnes, 1983), pigs (Goehring *et al.*, 1984; Mahan and Parrett, 1996), lambs (Molnar *et al.*, 1998), beef and dairy cattle (Ekholm *et al.*, 1991; Pehrson *et al.*, 1999). Other studies also indicate that the source of selenium plays a role in terms of selenium effectiveness when the source is organic: either from naturally high selenium feeds (Lawler *et al.*, 2004) or supplementation with selenium yeast (Edens, 1996, Mahan and Parret, 1996; Pehrson *et al.*, 1999). Jacques (2001) has suggested that selenium status during critical points of growth, reproduction, stress or disease challenge depends on the presence of readily mobilized tissue reserves. When the diet includes organic selenium in the form of selenomethionine from forages, grains or selenium yeast, this seleno amino acid is incorporated into general body proteins, preventing losses via urinary excretion, and releases selenomethionine for selenoprotein synthesis through normal protein turnover mechanisms (Jacques, 2001). It is known that ruminants absorb sodium selenite poorly (Wright and Bell, 1966) and recent studies have shown that selenium from sodium selenite is poorly transferred to milk (Ortman and Pehrson, 1997). Research has shown that cows supplemented with selenium yeast are more effective at transferring selenium to calves via placental transfer and milk than cows supplemented with sodium selenite (Ortman and Pehrson, 1997; Pehrson *et al.*, 1999). For more details on organic selenium supplementation, the reader is referred to a number of excellent reviews on the topic (Surai 2000, Jacques 2001).

Selenium and Meat Quality

Based on the role that selenium plays as part of GSH-Px, it has been suggested that the source of Se utilized may have an impact on meat quality (Surai, 2000). A number of studies have evaluated effects on drip loss and color of meats when comparing sodium selenite and selenium yeast, however the results are not as clear-cut as for animal health and performance. Work by Edens *et al.*, (1996), first drew attention to the role of selenium yeast in positively influencing meat quality and yield. They found a greater reduction in drip loss when selenium yeast was used compared to sodium selenite (Table 1). Naylor *et al.*, (2000) supported these results reporting that organic selenium reduced the 24-hour drip loss in broiler carcasses by 23%. It was speculated that organic selenium reduced drip loss by maintaining integrity of the cell membrane therefore increasing water-holding capacity of the muscle. Downs *et al.*, (2000) also showed low drip loss in broilers breast fillets when birds were fed selenium yeast.

Table 1. Effect of selenium source and selenium level on broiler breast meat drip loss (adapted from Edens, 1996).

Selenium Level (mg/Kg)	% Drip Loss SS	% Drip Loss SP	
0.1	5.6	4.6	(a)
0.3	5.1	4.6	(a)

SS: sodium selenite
SP: Sel-Plex, selenium yeast
(a) Values significantly different at P<0.05

Muñoz and coworkers (as cited by Torrent, 1996) indicated decreased drip loss for porcine longissimus dorsi muscle when the source of selenium was selenium yeast (Table 2). Mahan *et al.*, (1999) showed a trend (p=0.12) towards reduced drip loss in pork muscle with selenium yeast when compared to sodium selenite. On the other hand, Wolter *et al.*, (1999) did not find any difference in drip loss between sources of selenium. Interestingly though, they saw a significant reduction of lumbar fat thickness and higher loin eye area in pork muscle.

Table 2. Effect of dietary selenium supplementation on drip loss for porcine longissimus dorsi muscle (adapted from Torrent, 1996).

		Time post-mortem (hours)			
		4	**48**	**72**	**120**
Whole muscle	Control	1.98	2.69	3.51	4.75
	Treatment	1.57	2.25	3.00	4.13
Steaks	Control[a]	4.70	6.74	8.75	10.74
	Treatment[b]	3.57	5.21	7.49	9.50

[ab]Treatments differ at P<0.07

Clyburn *et al.* (2001) studied the relationship between vitamin E and selenium on beef meat quality. They found no difference in drip or purge loss from the meat. However they found that lightness of lean muscle improved with 50% less vitamin E when organic selenium was used rather that sodium selenite. They also reported that taste appeal of steaks as judged by flavor and flavor intensity was improved for the organic selenium treatment and remained acceptable for a longer period of time compared to control or sodium selenite treatments. Similarly, Silva de Lyons (1998) reported improved flesh quality measurements in Atlantic salmon (Table 3) particularly pigmentation and texture.

Table 3. Effect of Sel-Plex (selenium yeast) on flesh quality of Atlantic salmon (adapted from Silva de Lyons, 1998).

	Control	Sel-Plex	Change (% of Control)
Color Roche score	14.9	15.2	2.01
Pigment, mg/Kg	6.7	7.4	10.45
Texture, Kg/cm^3	11.4	12.5	9.65
GSH-Px U/g Hb	53.3	107.3	101.30

More recently, Simek *et al.*, (2002), evaluated the effect of selenium sources on drip and fluid losses of vacuum packaged beef meat. They found that animals fed the longest (30 days) with organic selenium prior to slaughter, had the lowest drip loss when compared to control (sodium selenite) or short time feeding (7 days) of selenium yeast, though the effect was not significant. Interestingly they found a significant effect on fluid losses on the simulated retail package. The lowest fluid loss was achieved on the group fed selenium yeast for the longest period (Table 4).

Table 4. Drip and fluid losses from vacuum packed meat and stored for 4 and 8 days (adapted from Simek *et al.*, 2002)

	Drip loss (%)	Fluid loss 4 days (%)	Fluid loss 8 days (%)
Control	0.92	0.29[a]	0.69
SP-7 days prior	1.17	0.45[a]	0.40
SP-30 days prior	0.50	0.03[b]	0.65

Control: Sodium selenite
SP: Sel-Plex, selenium yeast
[ab]Within column means differ significantly at P<0.05

O'Grady *et al.* (2001) found no significant effect of dietary and source of selenium on the oxidative stability of minced longissimus muscle. They attributed this lack of response to the fact that there was no effect in GSH-Px activity as a consequence of the relatively high native selenium level in the basal diet. Muscle GSH-Px has been shown to respond to dietary Se in a number of species (Meyer *et al.*, 1981; DeVore *et al.*, 1983; Moksnes and Norheim, 1983). Silva de Lyons (1998) also reported increased GSH-Px activity when selenium yeast was used compared to sodium selenite in Atlantic salmon.

The combination of organic selenium and vitamin E supplementation (O'Grady *et al.*, 2001) showed a significant difference (p=0.05) when compared to control and organic selenium on its own but not vitamin E regarding meat quality (Table 5).

Table 5. Effects of dietary vitamin E and Se on some meat quality parameters (adapted from O'Grady *et al.*, 2001).

	Storage time at 4ºC (days) 0		7		14	
	OMb	TBARS	OMb	TBARS	OMb	TBARS
Control	73.1	0.24	50.2	1.91	32.2	2.86
+E	79.3	0.11	61.3	0.38	52.5	0.65
+Se	69.6	0.28	51.1	1.71	38.6	2.34
+E+Se	71.6	0.09	62.1	0.19	54.0	0.28

Control: 0.1 mg/Kg inorganic selenium
+E: control plus 300 IU of DL-α-tocopheryl acetate
+Se: control plus 0.3 mg/Kg of selenium yeast
+E+Se: control plus 300 IU of DL-α-tocopheryl acetate and 0.3 mg/Kg of selenium yeast

Similarly, Clyburn *et al.*, (2001) observed that vitamin E could be reduced by as much as 50% when selenium was used in the form of selenium yeast. This would suggest that organic selenium has the potential to accentuate the stabilizing effect of vitamin E. In fact it has been suggested (McDowell, 1992; Combs, 1981) that vitamin E and selenium are mutually replaceable and each act as a sparing mechanism for the other.

Functional Meat

As consumer awareness about health aspects and well being continues to increase the demand for foods that go beyond the satiety factor into health related benefits, the industry will be facing a number of challenges. If natural feeding programs go beyond niche markets, as is the case in some European countries, it will be important to further elucidate the impact that feeding strategies have on final meat quality. The kinds of ingredients and forages used can render the meat to be prone to oxidation and cause health problems if diets do not have sufficient vitamin E and Se levels. Mice that consumed a diet high in PUFA's (menhaden oil) showed severe cardiac muscle damage compared to control diets and diets adequate in Se and vitamin E when exposed to Coxsackie's virus (Beck *et al.*, 1994).

One of the main challenges, however, facing our meat industry today, is to enhance its image and to add value to the final product. Meat is a major dietary source of many macronutrients such as protein ("high protein" and "low carb" being the buzz words for consumers). Meat is also an excellent source of micronutrients such as zinc, iron, selenium and copper, as well as the vitamins folic acid and B12. Each of these micronutrients is linked to the maintenance of a healthy immune system and so it is perhaps time for the animal meat industry to further consider the products that it delivers to market not just in terms of consumer (organoleptic) preference, but also in terms of specific health benefits.

Knowledge of the importance of selenium status in human health and performance is increasing rapidly particularly in relation to immune response and cancer prevention (Rayman, 2000). Selenium research particularly selenium in the form of selenium yeast offers great opportunities both on the human medical and animal sciences.

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