Level and cooking stability of two trace-elements in bovine meat : iron and selenium, respectively pro- and anti-oxidant

V. Soucheyre* & E. Parafita
ADIV, 10 rue Jacqueline Auriol, ZAC Parc Industriel des Gravanches, 63039 Clermon-Fd cedex 2 France.
*E-mail: valerie.soucheyre@adiv.fr

Abstract

The aim of this study consists to 1) determine the contribution of bovine meat to the iron and selenium allowances for human according to the type of muscle, breed, storage and cooking conditions and 2) determine the role of the both elements on the peroxidation in meat because of their antagonist effects on this process. A glycolitic muscle (longissimus dorsi, LD) and oxidative muscle (triceps brachei, TB) are isolated from 16 animals (Charolais vs. Holstein). Beef are stored in packaging under modified atmosphere during 7 days. After 4 days of storage, LD is grilled, and TB is cooked in pan or braised. The type of muscle has an effect on the level of trace elements, the color, the TBARS level (indicator of peroxidation) and vitamin E level (antioxidant). Total antioxidant status and glutathione peroxidase activity (antioxidant indicators) are not modified. The storage has no effect on iron, selenium and vitamin E levels but affect the color and lipid stability. Cooking meat had various effects according to the temperature and the length of the thermic treatment. Temperature tends to decrease the biodisponibility of iron since it favors conversion of heme iron to nonheme iron and conversion of soluble iron to insoluble iron.

Introduction

100 g of bovine meat contains about 10 µg of selenium and 3mg of iron, so it contributes to the dairy allowances for human (40 µg/d and 14 mg/d). In the occidental diet, meat products are the main source of iron (30 to 35%) and particularly the red meat (Lopez & Martos, 2004). Essentially as an heme form, iron contained in meat is better bioavailable (15 to 25%) than iron in vegetables and milk products (<5 to 10%) (Sorensen *et al*., 2007). Heat treatments applied to meat are known to induce the conversion from heme iron to non heme iron (Purchas *et al*., 2004).This change can determine the iron bioavailability from meats.

In meat, selenium and iron have distinct roles on the peroxidation reactions. Selenium is the cofactor of the glutathione peroxidase (GPx) which is an antioxidant enzyme. Antioxidant role of selenium and vitamin E continue after the slaughter (Faustman e*t al*., 1990) so can protect meat during storage and cooking. Conversely, iron is one of the major catalysts of lipid oxidation. The heme form of iron is contained in the myoglobin pigment of meat which determined the fresh meat colour according to the redox state (Renerre, 1990).

The aim of this study is 1) to determine the impact of the storage and cooking methods on the level of iron and selenium in beef meat and 2) to study the prooxidant effect of iron and the antioxidant effect of selenium after storage and cooking steps.

Material and methods

Experiment was performed using 8 Charolais and 8 Holstein. 1 day post mortem, longissimus dorsi (LD) and triceps brachii (TB) have been stored under vacuum during 7 days at 3°C. Then, muscles have been cut and packaged under modified atmosphere (70%O_2 and 30%CO_2) during 1, 4 or 7 days, at 4°C. Meat samples stored during 4 days have been cooked: LD was grilled, TB was pan or braised. All samples of meat have been crushed with liquid nitrogen and stored at -20°C before analysis.

Level of total iron was determined by atomic absorption spectroscopy using a Perkin Elmer AA800 system. Heme iron was quantified using the Hornsey method (1956). Level of selenium was measured by gas chromatographic- mass spectrometric method with the conditions described by Ducros & Favier (1992). To analyze the pro-oxidant effect of iron, we have evaluated the colour of meat by reflectance spectroscopy in order to determine the redness (a*) with the CIELAB system and measured the oxygenation index according to the method described by Renerre (2000). The intensity of peroxidation process was determined by the measure of the thiobarbituric acid reactives substances (TBARS) using the method of Lynch and Frey (1993). GPx activity was measured by absorbance at 340 nm using the method described by Agergaars & Thode Jensen (1982), but only in the raw meat because cooking treatment inactive the enzyme. As GPx acts in synergy with vitamin E for

eliminate the lipid hydroperoxydes, the level of this vitamin was determined by HPLC with the method of Liu et al. (1996). The total antioxidant status (AOS) of meat was also evaluated using the method of Miller et al. (1993).

Data were analyzes by ANOVA using the Statview software. When a treatment response (effect of breed, muscle, storage time, cooking methods) was detected ($P<0,05$), the respective means of the groups were compared using the Student's t-test of Statview.

Results and Discussions

Level of total iron is between 1,93 and 2,82 mg/100 g of meat and there is no breed effect. Proportion of heme iron is higher in Charolais (85%) than in Holstein (67%). TB contain a higher amount of heme iron than LD (2,6 vs. 1,95 mg/100 g) probably due to the energetic orientation of muscle fibers (oxidative vs. gycolytic). The storage under modified atmosphere during 7 days has no effect on total and heme iron levels.

Coking has different effects according to the temperature and the length of the heat treatment (**Table 1**): when the LD was grilled, there is no effect on total iron and the both iron forms. For the TB, 100 g of braised meat gives 4,7 mg of total iron, thus 1,8 fold higher than the raw meat because of the loss of water (**Table 1**). In this case, heme iron represents only 38% of total iron after cooking. With the pan cooking, proportion of heme iron (70%) was unchanged compared to raw meat.

Table 1

Triceps brachii	**raw**	**braised**	**pan**
mg/100 g of raw or cooked meat			
Total iron	2,69 ± 0,48 [a]	4,71 ± 0,82 [b]	3,14 ± 0,63 [a]
Heme iron	1,96 ± 0,27 [a]	1,79 ± 0,20 [a]	2,22 ± 0,39 [b]
Non heme iron	0,73 ± 0,51 [a]	2,92 ± 0,73 [b]	0,92 ± 0,53 [a]

100 g of meat gives 9,7 µg of selenium that corresponds to 20% of the human recommendations. The storage with modified atmosphere not alters this level whatever the breed and the muscle considered. Cooking treatments leads to an increase of the selenium level (water loss) (x1,2 for the LD grilled and x 1,3 for the TB pan) which is more important when the cooking time increase (x1,9 with the TB braised).

Type of muscle have an impact on the colour of meat : oxidative muscles (TB) have a redness a* and an oxygenation index higher than glycolytic muscles (LD) ($P<0,01$) (**Table 2**). The storage during 7 days under modified atmosphere reduces the both parameters ($P<0,0001$).

Table 2

	Charolais			**Holstein**		
	1 day	**4 days**	**7 days**	**1 day**	**4 days**	**7 days**
Redness a*						
LD	24,90 ± 3,73	22,20 ± 2,89	22,11 ± 1,49	22,46 ± 4,64	21,62 ± 2,97	19,52 ± 3,87
TB	28,13 ± 1,84	24,15 ± 2,98	21,75 ± 2,71	25,61 ± 2,35	22,31 ± 2,14	20,51 ± 1,54
Oxygenation index						
LD	13,67 ± 2,83	12,37 ± 2,37	12,03 ± 1,50	14,02 ± 2,63	13,37 ± 2,12	11,72 ± 2,82
TB	40,03 ± 2,70	39,71 ± 2,60	40,23± 3,22	39,81 ± 5,60	36,27 ± 3,68	39,24 ± 4,25

The 7 days of storage increases peroxidation process (TBARS level increase by 68% for LD and 72% for TB, $P<0,0001$). Level of vitamin E is maintain (0,3 to 0,7 mg/100g according to the breed and muscle, **Table 3**). Antioxidant status (AOS) decrease after 4 days of storage (-8% to -15% according to the muscle) (**Table 3**).

Table 3

	Charolais			Holstein		
	1 day	**4 days**	**7 days**	**1 day**	**4 days**	**7 days**
Vitamin E mg/100 g						
LD	0,39 ± 0,19	0,48 ± 0,18	0,36 ± 0,12	0,58 ± 0,20	0,43 ± 0,08	0,40 ± 0,09
TB	0,47 ± 0,06	0,32 ± 0,07	0,26 ± 0,11	0,54 ± 0,17	0,65 ± 0,20	0,60 ± 0,18
AOS µmol/100 g						
LD	79,68 ± 17,9	73,18 ± 13,1	69,45 ± 6,9	104,75 ± 12,9	89,16 ± 9,6	85,65 ± 7,7
TB	63,04 ± 17,3	55,52 ± 12,3	55,78 ± 10,2	68,84± 4,5	61,49 ± 3,0	60,73± 2,1

For the TB paned, vitamin E increases (+24%, P<0,01) because of the margarine added initially (**Table 4**). When it was grilled, the AOS of the LD decrease by 63% (P<0,0001). For the TB, cooking decreases also the AOS by 10% when it was pan and by 24% when it was braised (P<0,0001).

Table 4

	LD		TB		
	Raw	Grilled	Raw	Braised	Pan
Vitamin E mg/100 g	0,46 ± 0,13	0,48 ± 0,15	0,48 ± 0,22	0,41 ± 0,21	0,74 ± 0,25
AOS µmol/100 g	81,17± 13,72	32,40± 8,99	58,51 ± 7,79	93,21 ± 17,66	55,20± 13,77

GPx activity was not influenced by muscle, race and storage time under modified atmosphere.

Conclusion

The type of muscle is a key factor which determines the level of selenium and iron. Level of iron, selenium and vitamin E are higher in TB (oxidative) than in LD (glycolytic). Several authors demonstrated that supplementation with selenium and vitamin E reduces myoglobin oxidation thus can have an impact on redness and AOS. Relation between TBARS and GPx activity has been demonstrated by Hoac et al. (2005). O'Grady et al. (2001) demonstrated that vitamin E impact on GPx activity. Cantor et Tarino (1982) have suggested that GPx activity depends on the level and the form of selenium. In this study, correlations between iron or selenium status and antioxidant and peroxidation indicators have not been established.

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