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SUITABILITY OF LOW RESOLUTION NUCLEAR MAGNETIC RESONANCE TO ASSESS WATER HOLDING CAPACITY OF RABBIT MEAT

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SUMMARY - Water holding capacity has been studied on *Longissimus dorsi* muscles of growing rabbits reared in intensive system. The research work has been conducted on 48 carcasses, 48 h *post mortem*, by performing the same analyses which have been found useful for the assessment of water holding capacity in pork meat. Two different water compartments are detected by Low Resolution Nuclear Magnetic Resonance (LR-NMR), having long and short proton relaxation times, T_{2a} and T_{2b}, respectively. Relaxation time T_{2a} has been associated to protons of water less tightly held by meat structure itself with respect to water having relaxation time T_{2b}. In addition, LR-NMR provides the relative amount of water having these two different relaxation times. The parameter α is defined as the ratio between the amount (P) of water with T_{2a} and the total amount of water detected in meat by NMR [$\alpha\%=P_{T2a}/(P_{T2a}+P_{T2b})$]. The average values of T_{2a} (115.1±1.8 ms) and T_{2b} (42.5±1.3 ms) in rabbit are both significantly higher than those found in *Longissimus dorsi* of pigs, while α resulted significantly lower in rabbit than in pork meat (12.3 *vs.* 17.2 %, P<0.01). T_{2b} is negatively correlated (P<0.01) to drip loss and the latter is positively correlated to the lightness parameter of color (L*). Both correlations thus confirm the results obtained in a previous study focused on pork meat.

Key words: Water holding capacity, meat, NMR, drip loss.

RESUME *- On a etudiè le pouvoir de rétention d'eau du muscle long dorsal des lapins élevés en conditions intensif. La réchérche a utilisé 48 carcasses, 48 heures après l'abattage, en utilisant les mêmes analyses qui ont été menées pour établir le pouvoir de retention d'eau chez la viande de porc. Deux differentes compartements d'eau ont été détectés par la Résonance Magnétique Nucléaire à basse Résolution (LR-NMR) avec un long et un court temps de relaxement protonique,* T_{2a} *e* T_{2b} *réspectivement.* T_{2a} *a été associé aux protons de l'eau fortement retenue par la même structure de la viande, tout en respectant le* T_{2b}*. De plus, LR-NMR a établi la quantité d'eau relativement aux* T_{2a} *et* T_{2b}*. Le parametre* α *a été defini comme le rapport entre la quantité (P) de l'eau avec* T_{2a} *et la quantité totale de l'eau detectée dans la viande par NMR. Les valeurs moyennes de* T_{2a} *(115,1±1,8 ms) et* T_{2b} *(42,5±1,3 ms) chez le lapin sont significativement plus élevées à celles qu'on a trouvé dans le muscle long dorsal du porc, alors que* α *était significativement plus bas chez le lapin (12,3 vs. 17,2 %, P<0,01).* T_{2b} *est negativement correlé (P<0,01) aux pertes de jus qui sont par contre positivement correlées au paramètre L* de la couleur. Ces resultats confirment ce qu'on a trouvé dans la viande de porc par nos essais antérieurs.*

Mots-clés: *pouvoir de rétention d'eau, viande, RMN, pertes de jus.*

INTRODUCTION

Water holding capacity is a qualitative parameter of primary importance in meat industry, because the sensory characteristics of such a product, as well as the suitability to its storage and processing, are strictly influenced by the binding of water to meat.
Moreover, drip loss represents a relevant commercial damage, consisting in the decreased weight of the final product and in loosing of some nutritional value associated to the relatively high concentration, about 2/3 of that found in muscle, of proteins dissolved in the exudate. At last, high drip

loss originates a shorter shelf-life of the product, even after processing, because of the oxidative and hydrolytic processes promoted by microorganisms easily developing in the exudate. This holds especially in hot climate countries where the environmental conditions (temperature and relative humidity) are even more favorable to microbial development, if the storage conditions are not strictly kept under control.
Drip loss is mainly due to the shrinkage phenomenon caused by the *post-mortem* pH fall which denatures myosin and, consequently, decreases its hydration capability and reduces myofibril volume. Since myofibrils constitute a relevant fraction of the muscle bundles (about 80%, Offer and Knight, 1989), such a phenomenon highly modify water distribution inside the meat, thus increasing the amount of "less tightly bound" water which tends to be lost.
Low resolution nuclear magnetic resonance (LR-NMR) has been used to investigate the water distribution in meat (Tornberg *et al.,* 1993; Renou, 1995; Capozzi and Cavani, 1996; Petracci, 1997). This spectroscopic technique, mostly exploited in other application fields, is a powerful tool for the characterization of different dynamic states of water through the measurement of transverse relaxation times (T_2) of its protons (Zimmerman and Lasater, 1958). In fact, bulk water has longer proton T_2 than hydration water, especially if the latter is bound to macromolecules (*i.e.* proteins).
Different water compartments can be localized in muscles, each having its own characteristic composition of proteins and other solutes. Moreover, these compartments are characterized by different size of spaces through which the water can freely diffuse (Lee *et al.*, 1992).
The measurement of the nuclear relaxation times provides information about the interactions existing between water and muscle, as well as the amount of water localized in different muscle compartments (Lee *et al.*, 1992).
In this research we have studied the relationship between the water proton relaxation times and some qualitative variables of rabbit meat. Moreover, a comparison between NMR parameters found in pork and rabbit meat has been performed.

MATERIAL AND METHODS

Forty-eight hybrid rabbits, slaughtered when 10-11 weeks old, have been utilized for this research work (Maertens *et al.*, 1998). All the experimental data arise from the analysis of samples of *Longissimus dorsi* removed from carcasses kept at 0-4°C for 48 hours. The measurements of color parameters (L*, a*, b*) have been performed, according to Cielab system, with a Minolta Cr-300 apparatus. pH has been measured at 48 hours *post-mortem* (pH_{48}) by using a glass electrode with a conic tip (Double Bore, Hamilton), by averaging three independent measures. Drip and cooking loss, are determined following methods reported by Kaufmann *et al.* (1986), and Honikel (1987), respectively. Humidity, proteins and muscular fat contents have been measured by following standard analyses methods recommended by AOAC (1990). NMR parameters have been determined by using a Minispec Bruker PC120 operating at 0.47T. Samples rod have been excised from *L. dorsi* muscle and inserted in the NMR tube in such a way that the muscle bundles resulted parallel to the external magnetic field. Forty-four heavy pigs carcasses (average weight = 133.9 kg), slaughtered according to normal industry procedures, have been selected for comparison of NMR parameters. The Carr-Purcell sequence pulse, modified according to Meilboom and Gill (1958), has been applied.
Statistical analysis of data was performed by using the "Statistica for Windows" package (r. 4.0, 1993). Linear correlation analysis (Pearson's coefficients) and t-test for independent samples have been performed.

RESULTS AND DISCUSSION

NMR data fit evidenced two different types of water each one characterized by its own proton transverse relaxation time (T_{2a} and T_{2b}, respectively, in Table 1). The two population of water have been estimated to be present in rabbit meat at a ratio which is represented by the parameter α. The average value of 12.3±0.3% is consistent with the hypothesis that the water having longer proton relaxation time (T_{2a}) corresponds to the water outside the muscle fibers (Capozzi and Cavani, 1996). In Table 1 are also reported the results of the other standard analysis used for characterization of rabbit meat.
Significant simple correlation (P<0.01) among the overall qualitative variables determined in the 48 rabbit meat samples are shown in Table 2. Interestingly, T_{2b} is again negatively correlated to drip loss, thus confirming our prevoius results found in heavy pig meat (Capozzi and Cavani, 1996). Furthermore, T_{2b} is also negatively correlated to the water distribution parameter α (-0.50, P<0.01),

showing that the *post-mortem* shrinkage of meat causes: (i) a reduction of the internal space of fibers, as indicated from the shortening of T_{2b}; and (ii) a net flow of water from the inner space of the fibers towards outside, as indicated from the increasing α.

Table 1. Descriptive statistics of analytical data (N=48)

Parameters	Mean	SD	CV%	Min	Max
Loin wt. (g)	254.8	21.6	8.48	219.9	299.4
Kidney fat wt. (g)	21.6	7.05	32.7	10.8	42.9
NMR parameters:					
T2a (ms)	115.1	8.87	7.70	97.1	136.5
T2b (ms)	42.5	1.45	3.41	39.3	46.0
α (%)	12.3	2.06	16.69	8.88	17.22
Color parameters:					
L*	60.4	1.91	3.17	56.0	64.5
a*	2.19	0.70	32.2	0.90	3.86
b*	2.27	0.91	40.2	-0.24	3.93
Drip loss (mg)	64.9	9.61	14.8	43.9	85.9
Cooking loss (%)	28.8	2.68	9.30	23.9	37.0
Humidity (%)	75.0	0.65	0.87	72.7	76.7
Protein (%)	23.4	0.56	2.37	22.1	24.6
Fat (%)	0.93	0.41	44.4	0.36	2.60

Table 2. Simple significant correlations (P<0.01) among NMR parameters and other quality variables

Parameters	T_{2a}	T_{2b}	α	pH_{48}	L*	a*	b*	DL	CL	H	P	Fat
Kidney Fat				-.42								
T_{2a}	1.00											
T_{2b}		1.00	-.50					-.48				
α			1.00									
pH_{48}				1.00								
L*					1.00		.59	.37				
a*						1.00	.48					
b*							1.00					
Drip loss (DL)								1.00				
Cooking loss (CL)									1.00			
Humidity (H)										1.00		
Protein (P)											1.00	
Fat												1.00

Drip loss, up to know taken as the main parameter to describe water retention, is resulted to be positively correlated to the lightness L* color parameter (0.37, P<0.01), confirming that, even in rabbit, paleness is associated to the tendency of meat to loose water. A further finding is that a correlation exists between pH_{48} and the perirenal fat amount of carcass(-0.42, P<0.01), indicating that mature rabbits have a higher glycolytic potentiality.

The comparison between pork and rabbit meat (Table 3) shows that water proton relaxation times are longer in rabbit than in pork, thus suggesting that spaces internal and external to fibers are both larger in rabbit. On the other side, the relative amount (α) of water outside the fibers is lower in rabbit meat than in pork, thus indicating a lower tendency of rabbit meat to loose water.

Table 3. NMR parameters in rabbit and pork meat (mean±S.E.)

NMR parameters	Rabbit (N=48)	Pork (N=44)	P<
T2a	115.1±1.3	109.1±1.8	0.01
T2b	42.5±0.2	41.0±0.3	0.01
α	12.3±0.3	17.2±0.5	0.01

CONCLUSIONS

The results of this research work confirm that, also in rabbit, NMR parameters are suitable for the determination of water holding capacity of meat. In fact, strict correlation between drip loss and NMR parameters have been found. Moreover, the NMR parameters evidenced a good water retention of rabbit meat. This distintive feature looks promising for the improvement of the shelf life of fresh and processed meat products, making the rabbit meat suitable for diffusion in hot climate regions.

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