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MUSCLE pH_{60}, COLOUR (L; a; b) AND WATER HOLDING CAPACITY AND THE INFLUENCE OF POST-MORTEM MEAT TEMPERATURE

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INTRODUCTION

Meat quality is a complex, multivariate system of physical-chemical parameters. Among the related physical characteristics, water holding capacity (WHC) is one of the more economically important attributes. For the consumer it affects the appearance before cooking and the mouth-feel during consumption and for the industry it affects processing yield as drip loss and the final product attributes (consistency, colour and saltiness).

In determining WHC of meat, the post-mortem rate of fall of pH is an important factor. A rapid muscle pH decline determines the denaturation of sarcoplasmic (Bendall 1973) and myofibrillar proteins (Stabursvik *et al.*, 1984), increasing the tendency of actomyosin to contract, affecting the amount of fluid free to come out in extra cellular spaces and the meat structure (paleness).

The early assessment of the three WHC categories of meat (PSE/Normal/DFD) by the objective methods available (Kauffman *et al.*, 1986) are time consuming and difficult to apply under field conditions. Because speed is absolutely essential and the damaging of meat in order to define the overall carcass quality (Kauffman *et al.*, 1991), is discouraged, subjective methods are usually adopted. However, the relationships between objective measurements and subjective scores found in different countries (Bendall 1988), because of differences in human physiological and psychological responses, have not been quite coincident.

The objective of this study to investigate colour (L, a, b) and pH_{60} as predictors of the WHC characteristics after 24 hours of chilling storage or the influence of a deep freezing procedure on pork.

MATERIALS AND METHODS

One hundred and eighty pig carcasses (Large White, LW; Belgium Landrace, LR; LWxLR cross bred) were randomly selected on the slaughter line at approximately one hour post-mortem, after a cooling regime of -4°C with 4m/s of air speed for 45 minutes. After temperature (portable Fluke 52K/J thermometer - K type thermocouple, John Fluke Mfg. Co., Inc., USA) and pH measurements (Portable pH meter HI 8314, HI 2031 electrode, Hanna Instruments, Limena, Italy) in the unexcised *m.longissimus dorsi* between the third and fourth last ribs were made, the corresponding deboned piece of muscle was sliced into four steaks 1.5cm thick (approximately 80g), cleaned of superficial fat, and packed into sealed plastic bags without special care with the inside air volume.

Two steaks were held in refrigeration (±4°C) for 24 (REF-24) and 48 hours (REF-48) for separated drip loss (Honikel *et al.*, 1986) and colour evaluation (Colorgard System/05, BYK-Garden Silver Spring, MD 20910 USA). Each colour value (Hunter system) was the mean of the three readings on a minced sample (Moulinex cutter).

The other steaks were immediately frozen on dried ice (-60°C) and after 24 hours of storage, drip losses were evaluated after complete sample thawing (no hard-core touch feeling) at room temperature ($F\text{-}th_{20°C}$) and at 4°C during ±24 hours ($F\text{-}th_{4°C/24h}$). Both steaks were held an additional 24 hours at refrigeration for additional drip loss and colour measurements ($F\text{-}th^{20°C/24h}$ and $F\text{-}th_{4°C/48h}$), according to the methods referred to above.

The data were analyzed using the factorial model analysis of variance based on the completely randomized block experimental design. Differences between means were compared with the least significant difference at the 95% level (95% LSD) calculated from the residual mean square.

RESULTS AND DISCUSSION

Table 1 shows the correlations between pH_{60}, colour parameters (L, a, b) and drip loss in pork *m.longissimus dorsi*. pH_{60} showed the highest correlation with drip loss, whereas the correlations with drip loss and the colour parameters were lower. These figures express the influence of pH on the distance separating myosin filaments and their cross-sectional area (Honikel *et al.*, 1986), increasing the amount of liquid in the interfibrillar spaces (Bendall 1973), and a variety of factors affecting the latter parameters. If the muscle structure affects the reflected light on the meat surface, its colour is basically dependent on the amount and chemical form of the heme-pigment present (Johansson *et al.*, 1991).

Considering that a 2% drip loss is the maximum amount of liquid purge that can occur prior to compromising the appearance of the meat in the package, the pH_{60} index is a poor predictor of WHC at 24 hours post-mortem (Figure 1). By the use of this index, approximately 18% of the samples would erroneously be considered to have acceptable WHC.

Considering L values of less than or equal to 55 as indicators of normal coloured meat and L values greater than 55 as indicators of pale coloured meat (Kauffman 1991), we can see from Figure 2 that many of samples (n=46), defined as red or reddish, have unacceptable drip loss, whereas, nine samples classified as pale would not exude at all after 24 hours in refrigeration.

Similar results were shown by Kauffman (1991), who created a five point meat classification system based on its colour/WHC relationship, in order to differentiate from meat scored on the classical scale (PSE, NORMAL and DFD). The distinct myofibrillar metabolic profile provide an acceptable explanation for the variation of pig meat quality (Monin *et al.*, 1986; Monin 1988).

The means and standard deviations of colour parameters, drip loss and pH_{60} for meat quality with categories of the Kauffman classification system, are presented in Table 2. The results are quite similar, except those found for pale and red meats with unacceptable drip loss. Despite the possible differences existing between drip loss evaluation methods, pale meats presented almost double the amount of drip than red meats, whereas Kauffman did not find any significant differences. Differences in the number of samples analyzed between the two studies may have influenced the interpretation of the results.

The finding of one dark sample with unacceptable drip loss in our classification is of minor importance. Attending to the initial pH, the associated L value could be related with problems in that particular animal or more likely, with a deficient bleeding operation.

Since the early sixties (Briskey 1964), fast post-mortem cooling of meat has proved to be a good handling procedure to prevent the development of PSE meat.

Drip loss, based on the comparison of fast, deep-frozen (-60°C) to refrigerated samples (+4°C) from the different meat categories, was dependent of the thawing temperature (Table 3). Samples thawed at room temperature ($F\text{-}th_{20°C}$), had an increasing amount of exudation. This tendency was more evident in meat that originally had an acceptable drip loss rate, independent of its pale or red colour. A different behaviour was seen for samples thawed under refrigeration for 24 hours ($F\text{-}th_{4°C/24h}$). Meat with unacceptable exudation had less drip loss for red but no significant change for pale

meats.

This data is in agreement with that reported by Locker *et al.* (1975) for lamb and mutton, with respect to the influence of the temperature in thaw rigor development and its effect on the subsequent final drip loss. Subjective evaluation of texture indicated significant increase in the F-$th_{20°C}$ meat toughness (hoodlike feeling). This phenomenon was less for the F-$th_{4°C/24h}$ samples. When such an increase in toughness occurred, this characteristic was still present after a storage period of 24 hours at ±4°C. The higher frequency in red meats can be explained by their myofibril slow metabolic profile post-mortem, presenting more ATP in the time of freezing, expressed by a higher pH_{60} value (Table 2). Similar findings have been reported by Dransfield and Lockner (1985), Barton Gade *et al.* (1987) and Moller and Vestergaard (1987) in which a rapid chilling of excised pork may result in tougher meat.

In the F-$th_{4°C/24h}$ the change in the percent drip loss, referred to above, must be more related with cold-shortening, as the thawing at low temperature reduces the thaw rigor (Honikel *et al.*, 1980). In such situations the negative influence in liquid loss rate is only expressed after some time of storage.

Regardless of the thawing temperature and meat category, drip loss increased when samples were held for 24 hours or more in refrigeration (F-$th_{20°C/24h}$ and F-$th_{4°C/48h}$). Unless cold shortening and thaw rigor could be controlled, the use of an early and deep freezing procedure should be avoided. People have increasingly less time for home cooking and the use of room temperature thawing or even more drastic methods (frying or roasting in the frozen state) are generally applied. However, if the pork muscle ATP-ase activity is still present at -18°C (Locker 1985; Wagner and Añon 1986), long term storage can reduce the negative influence of thaw rigor, enhancing the final quality of the meat.

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Table 1. Correlations among pH_{60}, colour parameters (L, a, b) and drip loss in pork *m.longissimus dorsi*.

	pH60	Drip loss	L	a	b
Drip loss	-0.647	1			
L	-0.208	0.309	1		
a	0.113	-0.105	-0.325	1	
b	0.11	-0.021	-0.021	0.322	1

Table 2. pH60, drip loss and colour parameters (L, a, b) means and standard deviation values of different meat categories.

	n	pH60	Drip loss	L	a	b
Red accept.	101	60.6± 0.23^{a}	1.01± 0.38^{a}	51.47± 0.21^{b}	21.61± 1.69^{a}	15.11± 0.89^{a}
Pale accept.	9	6.22± 0.17^{a}	0.93± 0.42^{a}	58.39± 1.80^{b}	19.19± 1.449^{b}	16.02± 0.55^{b}
Dark accept.	11	6.16± 0.29^{a}	1.03± 0.48^{a}	45.87± 0.93^{c}	22.61± 2.67^{a}	13.88± 1.21^{c}
Red unacc.	46	5.74± 0.21^{b}	3.73± 1.54^{b}	52.01± 2.23^{a}	21.87± 2.43^{a}	14.90 0.98^{a}
Pale unaccp.	12	5.57± 0.21^{b}	6.03± 3.99^{c}	57.48± 1.40^{b}	19.84± 0.84^{b}	15.59± 0.47^{ab}
Dark unaccp.	1	5.86	2.27	46.64	27.02	15.20

Means with different superscripts in the same row are significantly different ($P<0.05$).

Table 3. Comparison of drip loss mean values between refrigerated and frozen samples for the different meat categories.

	Red acceptable	Pale acceptable	Red Unaccept.	Pale Unaccept.
n	101	9	46	12
REF-24	10.4 ±0.40a	1.08 ±0.45a	3.65 ±1.38a	4.48 ±1.62a
REF-48	2.70 ±1.50a	2.78 ±1.26a	5.66 ±1.40b	6.92 ±1.65b
F-th$_{20°C}$	5.97 ±5.48b	5.64 ±5.68b	5.16 ±2.57ab	5.98 ±4.08a
Fth $_{20°C/24h}$	9.17 ±5.15c	10.01 ±5.31c	7.97 ±2.83c	9.71 ±3.91c
REF-24	1.02 ±0.42b	0.88 ±0.56a	3.65 ±1.22a	4.74 ±1.95a
REF-48	3.23 ±1.34b	3.92 ±3.17b	6.25 ±3.20b	8.39 ±3.52b
F-th$_{20°C}$	1.32 ±1.05a	2.60 ±1.79b	2.38 ±1.39a	4.96 ±2.39a
F-th $_{20°C/24h}$	5.27 ±1.74c	6.97 ±2.65c	7.37 ±2.16b	9.42 ±2.46b

In the same column, means with different superscripts are significantly different ($P<0.05$).