PE4.11 Rapid chilling of carcasses and earlier deboning to improve WHC of pork semimembranosus muscle 33.00

V Tomovic (1) tomovic@uns.ns.ac.yu, L Petrovic(1), N Dzinic 1, P Ikonic 2 T Tasic 2 M Jokanovic 1
(1)Faculty of Technology, Novi Sad, Serbia
(2)Institute for Food Technology, Novi Sad, Serbia

***Abstract*– The effect of rapid air chilling of carcasses in the first 3 h of chilling at –31°C (then at 2 to 4°C, till 24 h *post-mortem*) and the possibility of earlier deboning (8 h *post-mortem*) after rapid air chilling, compared to conventional air chilling (at 2 to 4°C, till 24 h *post-mortem*) on water holding capacity of pork *M. semimembranosus* was investigated. Carcasses that were rapid chilled had significantly lower (*P*<0.001) internal temperature in the deep leg compared to conventional chill treatment. Rapid chilling reduced significantly (*P*<0.05) the rate of pH value decline at 8 h (6.02) *post-mortem* in *M. semimembranosus* compared to conventional chill treatment (5.88). Under the rapid chilling conditions, weight loss was 0.8% at 8 h *post-mortem* and increased to 1.4% at 24 h *post-mortem* when weight loss was 2.0% under conventional chilling. Compared to conventional chilling, in *M. semimembranosus* deboned in different time *post-mortem*, rapid chilling had a positive significant effect on cooking loss (*P*<0.001) and drip loss (*P*<0.05, muscles deboned 8 h *post-mortem*). Rapid chilling i.e. rapid chilling and earlier deboning had neither positive nor negative significant effects (*P*>0.05) on amount of exudative juice and wetness.**

V. M. Tomovic (corresponding author, tomovic@uns.ns.ac.yu), Lj. S. Petrovic, N. R. Dzinic and M. R. Jokanovic, Faculty of Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia.

P. M. Ikonic and T. A. Tasic, Institute for Food Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia.

***Index Terms*— Earlier deboning, Pork (*M. semimembranosus*), Rapid chilling, Water holding capacity**

I. INTRODUCTION

Due to the danger of spoilage, meat has to be chilled soon after slaughter [1]. On the other hand, rate of heat transfer, i.e. relationship between the rates of temperature and pH value decline can affect some other (technological) meat quality parameters (weight loss, tenderness, water holding capacity, color; [2]).

Water holding capacity (WHC) is of major concern in the meat industry, as it affects both economic and sensory attributes of the meat [3]. Weight loss of meat samples generally increases with storage time, however at a decreasing rate. The greatest amount of drip is generally lost during first 24 to 48 h [4].

Conventional, spray and rapid/accelerated chilling systems are commonly used for pork chilling in commercial practice today. Accelerated air chilling requires temperatures of –20°C to –40°C, often with an air velocity of 3 to 5 m/s for 1 to 3 h [5]. The use of different accelerated chilling systems, i.e. systems for rapid temperature decline of carcasses, can be an effective method to prevent or reduce the incidence of PSE (pale, soft, exudative) in pork [6, 7]. However, according to some literature data, the effect of rapid chilling on technological quality parameters of pork is limited [8, 9, 10].

One problem that may arise with accelerated chilling is cold shortening, which can occur if the temperature decreases too rapidly, i.e. while the energy level (level of adenosine triphosphate - ATP) in the muscle is still high [11]. To prevent cold shortening, it is recommended not to chill pork carcasses below 10°C in the first 5 h *post-mortem* [12, 13], i.e. not to chill below 5°C while the muscle pH value is above 6.0 [14]. Scientific studies under laboratory conditions [15] have suggested that rapid chilling can induce shortening of the muscle fibres (sarcomeres) and result in tough meat if a muscle temperature below 10°C is achieved within 3 h after slaughter when the muscle pH value is above 6.0, i.e. when the pH value fall is slow [16].

Having in mind these findings, and the fact that the ultimate pH value is reached in pork with normal glycolysis rates and most biochemical processes (rigor mortis) are completed, within 6 - 9 h *post-mortem* [1], i.e. 6 - 12 h *post-mortem* [17], and considering the EU directives for fresh pork [18] according to which pork must not be cut and deboned before reaching 7°C in the deep leg [1, 19], the aim of the study was to determine the effect of rapid air chilling of carcasses and time of deboning *post-mortem* on WHC of pork.

II. MATERIALS AND METHODS

A. *Experimental design*

Left carcass sides of the first 20 animals, average warm carcass weight of 74.5 ± 3.34 kg (including the head) were rapid air chilled (RC) in the freezing tunnel for 3 h at –31°C, with an air velocity 5 m/s, followed by conventional air chilling in temperature equalisation chill room at 2 - 4°C, with an air velocity 0.5 m/s, till 24 h *post-mortem* (pm). Left carcass sides of the second 20 animals, average warm carcass weight of 76.4 ± 4.19 kg were chilled in the same way, except that RC left carcass sides were cut and deboned 8 h pm. All 40 right carcass sides were conventionally air chilled (CC) at 2 to 4°C, with an air velocity 2 m/s, till 24 h pm. The physico-chemical investigations of *M. semimembranosus* (SM) were performed at the start, during and after the chilling process.

B. *Weight loss measurements*

Water evaporation during chilling is expressed as the percentage of weight loss, measuring the mass of one carcass side at the end of the slaughterline (30 min pm) and at the end of the chilling process (8 h and 24 h pm).

C. *Meat quality measurements*

Temperature and pH value. Temperature was measured at the start, during and at the end of the chilling process in the deep leg, near the femur, in both sides of all carcasses, 30 min (T_{30min}), 4 (T_{4h}), 6 (T_{6h}), 8 (T_{8h}) and 24 (T_{24h}) h pm using a portable digital thermometer with a 12 cm stem. pH was measured in the center of both SM muscles of all carcasses at 30 min (pH_{30min}), 8 (pH_{8h}) and 24 (pH_{24h}) h pm using the portable pH meter equipped with an insertion glass combination electrode [20].

WHC. Exudative juice. Determination of the WHC (exudative juice) was based on measuring water (juice) liberated when pressure was applied to the muscle tissue. Exudative juice was assessed using a filter paper press method (FPPM) [21]. The difference between the areas of the pressed meat film and the wet area on the filter paper is a measure of the exudative juice or WHC. The *cooking loss* was determined by method as described by Honikel [22] with slight modifications. Meat samples (about 150 g) prepared in the shape of a cubicle, were put into polyethylene bags and placed in the water bath. After cooking for 60 min at 90°C, the samples were cooled at 2 - 4°C in the cooler. After equilibration the samples were taken from the bags, blotted dry and weighed. The cooking loss is expressed as the percentage of the initial sample weight. The *drip loss* [22] was determined on meat samples (SM) of about 100 g, free of external fat and connective tissue. The samples were hung by a nylon cord in a plastic bag, ensuring the meat had no contact with the juice in the bag. The drip loss is expressed as percentage of weight loss after 24 h (drip $loss_{24h}$) of storage at 4°C, from the moment of muscle deboning. *Sensory* panelist evaluated wetness (1 - very watery, 2 – watery, 3 – moist, 4 - moderately dry, 5 - dry [23]).

D. *Statistical analysis*. All data are presented as means ± standard deviation. The results were evaluated statistically using the analysis of variance and Duncan's multiple range test in the Statistical Analysis System [24].

III. RESULTS AND DISCUSSION

A. Changes in rates of temperature and pH decline

The initial average temperatures (Table 1) in left and right carcasses were identical, 41.6°C ($P>0.05$). In CC carcasses, 4, 6 and 8 h pm, the average temperatures were 32.7, 24.2 and 19.1°C. Highly significant lower temperatures were found ($P<0.001$) at same times respectively in RC carcasses. During chilling, the difference between temperatures of CC and RC carcasses increased. Temperatures below 7°C were reached in the deep leg somewhat before 8 h pm, i.e. the average temperatures measured at 8 h pm in RC carcasses were 6.2°C. Furthermore, a highly significant effect of RC on carcass temperature ($P<0.001$) was also found 24 h pm. The average temperature measured in CC carcasses, 24 h pm, was also lower than 7°C (5.1°C).

At the end of the slaughter line, the difference between average pH_{30min} values (Table 1) determined in SM muscles from RC carcasses (pH = 6.22) and CC carcasses (pH = 6.18), was not significant ($P>0.05$). However, during RC of SM muscles, i.e until 8 h pm, significant ($P<0.05$) slowing of the rate of pH value decline was observed. Eight hours *post-mortem* the pH of SM muscles was still high, i.e. the onset phase of rigor mortis had just started. A number of authors report rigor mortis starts at different pH values, but, for pork, always below 6.1 [1, 14, 15, 25]. At the end of chilling (24 h pm), average pH values were in the range characteristic for pork (5.3 - 5.8; [1, 17]). A numerically, but not significantly higher ($P>0.05$) average pH value (5.77) was found in SM muscles from RC carcasses compared to the average pH value determined in SM muscles from CC carcasses (5.70).

Comparing the relationship of rates of temperature and pH decline in the deep leg, in the present study and the relationship of rates of temperature and pH decline defined for pork (*M. longissimus dorsi*) by several authors [12, 13, 14, 15], it can be seen that the internal temperature in the deep leg of RC carcasses 3 h and 5 h pm was above 10°C. Also, at the start of rigor mortis in

RC SM muscles (pH = 6.02 at 8 h pm), the internal temperature in the deep leg was above 5°C.

B. Changes in weight loss

RC i.e. RC and earlier deboning affect the weight loss of carcasses (Table 2). In RC carcasses deboned 24 h pm, the average weight loss (1.4%) is significantly lower ($P<0.05$) compared to CC carcasses (2.0%). The average weight loss in RC carcasses deboned 8 h pm (0.8%) is highly significantly lower ($P<0.001$) compared to the weight loss found in CC carcasses, and significantly lower ($P<0.05$) compared to RC carcasses deboned 24 h pm. The significantly lower weight loss, determined in RC carcasses deboned 8 h pm compared to RC carcasses deboned 24 h pm, is the result of shorter chilling.

C. Changes in WHC

The effect of RC and the time of deboning on the WHC is presented in Table 2. Next to the end of chilling (8 and 24 h pm), in RC SM muscles, numerically but not significantly ($P>0.05$) better WHC, i.e. in RC SM muscles a numerically lower amount of exudative juice was found, compared to CC SM muscles. In the same time *post-mortem*, no significant ($P>0.05$) effect of different chilling rate of carcasses and different time of deboning *post-mortem* on wetness of SM muscles was found. On the other hand, the results obtained in the presented study confirmed once more that the cooking loss depends on the ultimate pH value [1]. A highly significant lower cooking loss ($P<0.001$) was found in RC SM muscles which also had a higher average pH value. The cooking loss decreased from 42.5% (CC SM muscles) to 38.1% (RC SM muscles, deboned 24 h pm) and to 37.8% (RC SM muscles, deboned 8 h pm).

Furthermore, the results obtained for the drip loss show the same trend as the ones for the cooking loss. Regarding the criterion for drip loss (non-exudative pork: drip loss < 6% after 48 h; [26]), the average drip loss of all investigated groups of SM muscles was at the level which corresponds to normal quality muscles. A significantly lower average drip loss ($P<0.05$), compared to CC SM muscles (1.71%), was found in RC SM muscles deboned 8 h pm (1.20%). The effect of RC on the drip loss decrease is more important in SM muscles deboned 8 h pm having in mind that deboning and sampling at an earlier time *post-mortem* results in a drip loss increase [4]. The average drip loss determined in RC SM muscles deboned 24 h pm (1.55%) is not significantly different ($P>0.05$) compared to the values obtained in other investigated groups of SM muscles.

The effect of RC on the improved water holding capacity can be explained either by a biochemical effect, i.e., by a direct temperature effect on the *post-mortem* energy metabolism, by a structural effect, i.e., a temperature-induced effect on the mobility and distribution of water in the muscles, or by a combination of both [3].

IV. CONCLUSION

Investigating the effect of RC of carcasses and the possibility of earlier deboning (8 h pm) after RC on WHC of SM muscles, compared to CC, the following was concluded:

- the RC of carcasses reduced the internal temperature in the deep leg at 4, 6, 8 and 24 h pm ($P<0.001$),
- in RC SM muscles the rate of the pH decline was lower at 8 h pm ($P<0.05$), but 24 h pm pH was not affected ($P>0.05$),
- the RC of carcasses reduced weight loss, from 2.0% (CC carcasses) to 1.4% (RC carcasses deboned 24 h pm; $P<0.05$) and to 0.8% (RC carcasses deboned 8 h pm; $P<0.001$),
- in RC SM muscles, deboned 8 and 24 h pm, a lower cooking loss ($P<0.001$) was found,
- in RC SM muscles, deboned 8 h pm, a lower drip loss ($P<0.05$) was found,
- RC had no significant effect ($P>0.05$) on amount of exudative juice and wetness.

ACKNOWLEDGEMENT

This study was suppored by the Ministry of Science and Technological Development of the Republic of Serbia, Project No. TR20037.

REFERENCES

[1] Honikel, K.O. (1999). Biochemical and physico-chemical characteristics of meat quality. Meat Technology, 40(3-5), 105-123.

[2] Savell, J.W., Mueller, S.L., & Baird, B.E. (2005). The chilling of carcasses. Meat Science, 70(3) 449-459.

[3] Bertram, H.C., Dønstrup, S., Karlsson, A.H., Andersen, H.J., & Stødkilde-Jørgensen, H. (2001). *Post mortem* energy metabolism and pH development in porcine *M. longissimus dorsi* as affected by two different cooling regimes. A ^{31}P-NMR spectroscopic study. Magnetic Resonance Imaging, 19(7), 993-1000.

[4] Van Moeseke, W., & De Smet, S. (1999). Effect of time of deboning and sample size on drip loss of pork. Meat Science, 52(2), 151-156.

[5] Huff-Lonergan, E., & Page, J. (2001). The role of carcass chilling in the development of pork quality. Facts, National Pork Producers Council, Pork Quality, American Meat Science Association (pp. 1-8). Available: http://www.meatscience.org/Pubs/factsheets/chilling.pdf

[6] Milligan, S.D., Ramsey, C.B., Miller, M.F., Kaster, C.S., & Thompson, L.D. (1998). Resting of pigs and hot-fat trimming and accelerated chilling of carcasses to improve pork quality. Journal of Animal Science, 76(1), 74-86.

[7] Springer, M.P., Carr, M.A., Ramsey, C.B., & Miller, M.F. (2003). Accelerated chilling of carcasses to improve pork quality. Journal of Animal Science, 81(6), 1464-1472.

[8] Eilert, S.J. (1997). What quality controls are working in the plant? In: Proceedings pork quality summit (pp. 59-63), National Pork Producers Council, Des Moines, Iowa, USA.

[9] Kerth, C.R., Carr, M.A., Ramsey, C.B., Brooks, J.C., Johnson, R.C., Cannon, J.E., & Miller, M.F. (2001). Vitamin-mineral supplementation and accelerated chilling effects on quality of pork from pigs that are monomutant or noncarriers of the halothane gene. Journal of Animal Science, 79(9), 2346-2355.

[10] Hambrecht, E., Eissen, J.J., de Klein, W.J.H., Ducro, B.J., Smits, C.H.M., Verstegen, M.W.A., & den Hartog, L.A. (2004). Rapid chilling cannot prevent inferior pork quality caused by high preslaughter stress. Journal of Animal Science, 82(2), 551-556.

[11] Locker, R.H., & Hagyard, C.J. (1963). A cold shortening effect in beef muscle. Journal of the Science and Agriculture, 14(2), 787-793.

[12] Honikel, K.O., & Reagan, J.O. (1987). Hot boning of pig carcasses: Influences of chilling conditions on meat quality. In: Accelerated processing of meat, A. Romita, C. Valin and A. Taylor (Eds.), Elsevier Applied Publishers, London, United Kingdom.

[13] Bowater, F. J. (1997). Economies of meat chilling and freezing. In: Proceeding of the institute of refrigeration (pp. 1-11), London, England. Available: www.fjb.co.uk

[14] Honikel, K.O. (1999). Influence of chilling of pork carcasses on physical quality traits. National Pork Producers Council Chilling Workshop. National Pork Producers Council, Des Moines, Iowa, USA.

[15] Dransfield, E., & Lockyer, D.K. (1985). Cold-shortening toughness in excised pork *M. longissimus dorsi*. Meat Science, 13(1), 19-32.

[16] Møller, A.J., & Vestergaard, T. (1987). Effect of delay time before chilling on toughness in pork with high or low initial pH. Meat Science, 19(1), 27-37.

[17] Smulders, F.J.M., Toldrá, F., Flores, J., & Prieto, M. (1992). New technologies for meat and meat products. Utrecht, The Netherlands: Audet Tijdschriften.

[18] Council Directive of 26 June 1964 (64/433/EEC) on health conditions for the production and marketing of fresh meat. Official Journal of the European Union, L 121, 1-30.

[19] Dransfield, E., Ledwith, M.J., & Taylor, A.A. (1991). Effect of electrical stimulation, hip suspension and ageing on quality of chilled pig meat. Meat Science, 29(1), 129-139.

[20] ISO 2917. (1999). Meat and meat products. Measurement of pH (Reference method).

[21] Grau, R., & Hamm, R. (1953). Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel. Naturwissenschaften, 40(1), 29-30.

[22] Honikel, K.O. (1998). Reference methods for the assessment of physical characteristics of meat. Meat Science, 49(4), 447-457.

[23] NPPC. (2000). Pork composition and quality assessment procedures. E. Berg (Ed.) (pp. 1-38), National Pork Producers Council, Des Monica, Iowa, USA.

[24] SAS. (1991). SAS/STAT User's guide, Release 6.03 Edition. SAS Institute Inc., Cary, NC, USA.

[25] Hamm, R., Honikel, K.O., & Kim, C.J. (1984). Veränderungen im schweine- und Rindermuskel nach dem schlachten; Ein beitrag zum problem des schlachtwarmentbeinens von schweinen. Fleischwirtschaft, 64(9), 1387.

[26] Joo, S.T., Kauffman, R.G., Kim, B C., & Park, G.B. (1999). The relationship of sarcoplasmic and myofibrillar protein solubility to colour and water-holding capacity in porcine *longissimus* muscle, Meat Science, 52(3), 291-297.

[27]

Table 1. Effect of chilling method and time of deboning on internal ham temperature and pH value of *M. semimembranosus*

Chilling method	CC	RC
Time of deboning	24 h pm	8 and 24 h pm
Ham temperature (°C)		
T_{30min}	41.6 ± 0.55	41.6 ± 0.59
T_{4h}	32.7^{A} ± 0.84	25.7^{B} ± 1.44
T_{6h}	24.2^{A} ± 0.74	13.0^{B} ± 1.40
T_{8h}	19.1^{A} ± 0.75	6.2^{B} ± 1.16
T_{24h}	5.1^{A} ± 0.36	3.8^{B} ± 0.53
M. semimembranosus pH		
pH_{30min}	6.18 ± 0.18	6.22 ± 0.27
pH_{8h}	5.88^{b} ± 0.18	6.02^{a} ± 0.16
pH_{24h}	5.70 ± 0.19	5.77 ± 0.22

^{AB} indicates significant difference at $P<0.001$; ^{ab} indicates significant difference at $P<0.05$.

Table 2. Effect of chilling method and time of deboning on WHC of *M. semimembranosus*

Chilling method	CC	RC	RC
Time of deboning	24 h pm	24 h pm	8 h pm
Weight loss (%)	$2.0^{Aa} \pm 0.56$	$1.4^{ABb} \pm 0.54$	$0.8^{Bc} \pm 0.44$
FPPM (cm^2)	5.74 ± 0.71	5.57 ± 0.87	5.63 ± 0.77
Cooking loss (%)	$42.5^{A} \pm 2.57$	$38.1^{B} \pm 4.76$	$37.8^{B} \pm 2.89$
Drip $loss_{24h}$ (%)	$1.71^{a} \pm 0.68$	$1.55^{ab} \pm 0.63$	$1.20^{b} \pm 0.46$
Wetness (1 to 5)	2.79 ± 0.25	2.80 ± 0.59	2.70 ± 0.42

$^{AB,\ ab}$ as for Table 1.