ELSEVIER

Meat Science **40** (1995) 245–251

0309-1740/95/$9.50

0309-1740(94)00047-6

Influence on Meat Colour of Spray-chilling the Surface of Pig Carcasses

F. Feldhusen,[a] T. Kirschner,[b] R. Koch,[b] W. Giese[b] & S. Wenzel[a]

[a]Institute of Food, Meat Hygiene and Technology & [b]Department of Medical Physics, Tierärztliche Hochschule Hannover Bischofsholer Damm 15, D-30173 Hannover, Germany

(Received 18 February 1994; revised version received 22 July 1994; accepted 2 September 1994)

ABSTRACT

The present study examines the influence of spray-chilling on the surface colour of the musculature, skin and spinal spongiosa of swine carcass halves. Thirty swine halves, of the commercial classification U, were divided into six experimental groups and chilled under varying conditions over a period of 20 h. *Three of the experimental groups were sprayed periodically with* 810 g *drinking water within a* 4-h *chilling phase. The other three served as unsprayed control groups.*

Oxygenation of the myoglobin to oxymyoglobin was accelerated by spraying the surface of the musculature. Spray-chilling conditions had no influence on the formation of metmyoglobin. The colour of the sprayed ham musculature became lighter after 4 h *of chilling. Red- and yellow-values decreased. There were no significant differences in the colour values after* 20 h *of chilling. The surface of the skin became lighter after spray-chilling. The spraying had no influence on the colour of the spinal spongiosa.*

INTRODUCTION

Efforts have been made for some time to achieve an accelerated cooling of carcass while simultaneously reducing weight losses by using new technologies in the cooling of cattle and swine carcass halves (sides). Towards the end of the 1980s, the method of 'spray-chilling' for the cooling of beef was introduced in the United States (Allen *et al.*, 1987). The effects of this method on cooling processes and weight losses have been studied repeatedly (Allen *et al.*, 1987; Jones & Robertson, 1988a, 1988b; Feldhusen, 1993). Feldhusen (1993) additionally demanded a thorough examination of quality alterations such as the surface colour of the carcass halves for evaluation of the spray-chilling method. In the

marketing of carcass halves and fresh meat, meat colour is associated with the quality of the product (Romans & Norton, 1989).

The colour of meat is defined among other factors by the proportion of myoglobin, oxymyoglobin and metmyoglobin in the tissue (Johansson, 1989). Examinations of pork showed that the drying rate of the carcass surface had a stronger influence on the meat colour than the oxidation of myoglobin in the tissue (Feldhusen & Reinhard, 1994). After storage under practical conditions, the influence on the colour of segments taken from spray-chilled carcass halves has already been examined (Jones & Robertson, 1988a, 1988b; Jones *et al.*, 1988; Lauren *et al.*, 1990). Detrimental influences were not significant in beef and only minor in pork. In general, the influence of spray-chilling on the surface colour of carcasses is still uncertain (Feldhusen, 1993). In this study its effect on the surface colour of swine carcasses was examined.

MATERIALS AND METHODS

The sample material consisted of 30 freshly slaughtered swine halves of the commercial class U. Each half weighed 43·0 kg (± 1·0 kg). The sample material was divided into six different groups of five halves each. The cooling and spraying in the first phase (0–4 h cooling time) was carried out after 1 h *post mortem* in an experimental cooling system under the conditions shown in Tables 1 and 2. For the second phase of up to 20 h cooling, a temperature of +1°C, an air velocity of 0·2 m/s (1 cm above the ham surface) and a relative humidity of 90% was chosen. The water was sprayed on the carcass surface in a fine mist produced by

TABLE 1
Chilling Conditions for the Groups in the First Chilling Phase

Group/code	*Airspeed*	*Chilling temperature*	*Time*
+1/0,2/spray.	0·2 m/s	+1°C	4 h
+1/0,2/unspr.	0·2 m/s	+1°C	4 h
−10/0,2/spray.	0·2 m/s	−10°C	1 h
		+1°C	3 h
−10/0,2/spray.	0·2 m/s	−10°C	1 h
		+1°C	3 h
+1/0,6/spray.	0·6 m.s	+1°C	4 h
+1/0,6/unspr.	0·6 m/s	+1°C	4 h

TABLE 2
Intervals of Spraying and Sprayed Mass in the First Chilling Phase

Interval [min]	0–5	7–12	15–20	22–27	30	30–120	120–240
Water [g]	80	80	60	50	30	30 every 10 min	30 every 15 min

a common pneumatic spray-gun. The homogenous spraying mist ensured an even moistening of the surface. Just enough water was applied to the carcass half to moisten the surface completely without causing dripping. Altogether 810 g water at +20°C were applied during the 4 h spraying interval. Up to the end of the first cooling phase (4 h), the sprayed groups showed a weight loss of 0·1%. The respective control groups showed a weight loss of 1% during this time period. During the following 16 h in the second cooling phase, the weight loss of all experimental groups increased by 0·5%. The difference in weight losses of 1% between the sprayed and the unsprayed carcass halves remained constant until the end of the cooling (20 h).

Prior to and after cooling, *ca* 3 cm^2 sized skin samples were taken for the determination of the relative dry matter (%). The skin samples were taken from the regions of the ham, the neck and the loin, and a 0·5 cm thick muscle sample was taken from the medial ham side (*m. semimembranosus*). The skin was separated from visible subcutaneous fat and divided into small pieces with scissors. The relative dry matter was determined according to the official examination methods §35 LMBG (Lebensmittel- und Bedarfsgegenständegesetz, 1980). By determining the relative dry matter concentration in the skin during the various examination times, the respective increases in dry matter (%) after 20 h cooling time were calculated and statistically evaluated.

Myoglobin (%), oxymyoglobin (%) and metmyoglobin (%) as portions of the muscle surface were determined by reflectance spectrophotometry (Steward *et al.*, 1965). For the measurement, muscle samples, 2 cm diameter and 0·7 cm thick were cut from the medial ham side (*m. semimembranosus*) using a template.

The colour measurement (Lab-System) of the carcass surface was carried out with the Minolta Chromameter (Minolta, Ahrensburg). The musculature (*m. semimembranosus*) and the skin (lateral) of the ham as well as the spinal spongiosa in the region of the 1–3 thoracic vertebrae served as localisations for the measurements.

The percentage of myoglobin derivatives and the colour values were measured before the beginning of the cooling (0 h), at the end of the first cooling phase (4 h) and at the end of the total cooling time (20 h). The differences of single values from the time periods of 0–4 hours and 0–20 h were used for statistical evaluation which was carried out using a 2-factorial variance analysis of the statistics program SAS.

RESULTS AND DISCUSSION

Redox status of myoglobin

The colour of the muscle surface is influenced by the drying process as well as by the relative amounts of the three myoglobin redox-stages myoglobin (purple), oxymyoglobin (light red) and metmyoglobin (brown-gray) (Johansson, 1989; Feldhusen, 1994). The spray-chilling of the swine carcass halves decreased the drying off of the skin and the ham-muscle surface significantly in comparison to the unsprayed control group (Fig. 1). The damp carcass surface dried off gradually after each spraying. The sprayed water evaporated instead of the tissue fluid.

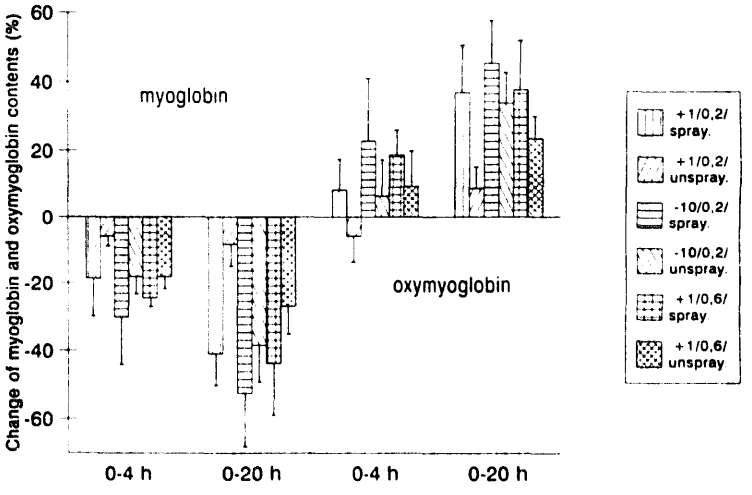

Fig. 1. Influence of spray-chilling conditions on the contents of myoglobin (%) and oxymyoglobin (%) of the medial muscle surface during chilling ($\bar{x}$, n = 5).

During cooling, the portions of myoglobin in the muscle surface decreased continuously in all cooling methods through oxygenation to oxymyoglobin and oxidation to metmyoglobin. The spraying accelerated the oxygenation of myoglobin to oxymyoglobin significantly ($P < 0{\cdot}05$) (Fig. 1). This caused an additional decrease in the myoglobin portion during the cooling phase 1–4 h as compared to the unsprayed control groups of *ca* 6–13%. Over 20 h cooling the differences amounted to 14–31%. The fast cooling conditions of the experimental groups +1/0·2 resulted in the least myoglobin oxygenation as compared to the other cooling conditions.

The oxymyoglobin portions increased during each cooling treatment (20 h) and correlated to the decrease in myoglobin portions (Fig. 1). The sprayed muscle surfaces showed an increase in oxymyoglobin. The formation of oxymyoglobin is favoured by a high oxygen concentration, whereas metmyoglobin dominates in a low oxygen tension (Ledward, 1970). By using a pneumatic spray-gun in these experiments, the applied spray water formed an aerosol (finest mist). Therefore the water layer applied to the carcass surface consisted of an O_2-enriched solution. The oxygen molecules were able to diffuse unhindered into the moist superficial muscle layer and were available for the oxygenation to oxymyoglobin. An intensified oxygenation of myoglobin in more humid cooling air was also noted in other experiments (Feldhusen, 1992). The formation of metmyoglobin was not influenced significantly by the spraying.

An increase in the cooling air velocity from 0·2 m/s to 0·6 m/s enhanced the decrease of myoglobin by an average of 10% during the first cooling phase (4 h) and simultaneously increased the portions of oxymyoglobin ($P < 0{\cdot}05$) (Fig. 1). In this experiment an increase in the cooling air velocity also led to an augmented oxygen supply at the surface of the carcass. Results by Lanier *et al.* (1977) showed the same effects. The largest decrease in the percentage of myoglobin occurred in sprayed carcasses by lowering the temperature of the cooling air from +1°C to −10°C during the first hour of cooling. This experimental

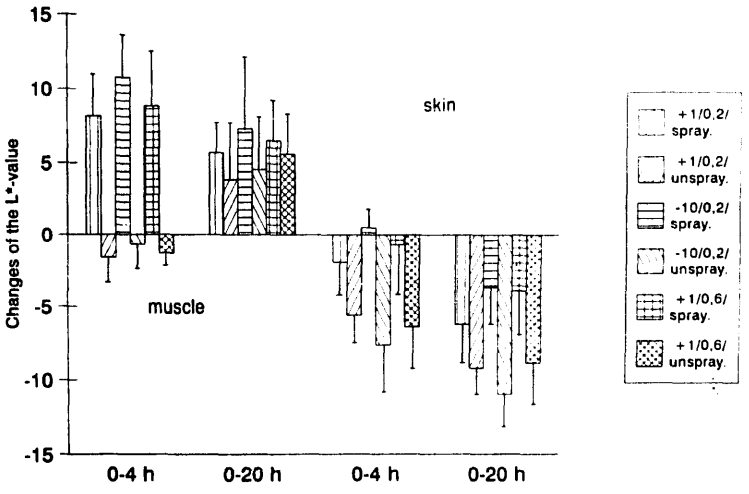

Fig. 2. Influence of spray-chilling conditions on the L^*-value of the muscle and skin surface during chilling ($\bar{x}$, $n = 5$).

group also showed the largest increase in oxymyoglobin. The oxygen saturation of water is dependant, among other factors, on its temperature and the substances dissolved in the water. The lower the temperature of the spraying water, the more O_2 molecules are absorbed. The large surface of the aerosol caused a fast balance of the spraying water temperature and the cooling air temperature, so that in the presented experiments the increased formation of oxymyoglobin by lowering the cooling air temperature was a result of the increased supply of oxygen molecules in the aerosol. The low rate mitochondrial respiration and the simultaneous oxygen saturation of the myoglobin additionally enhances an increase in the formation of oxymyoglobin at low temperatures (Cornforth *et al.*, 1985).

Colour

After 4 h cooling the lightness (L^*-value) of the *ham musculature* increased in the sprayed groups significantly ($P < 0{\cdot}05$) by 8–11 units as opposed to the unsprayed groups (Fig. 2). A drying and concentration of the muscle pigment occured on the muscle surface of the unsprayed carcasses during cooling storage. The meat colour of the sample surface of swine carcasses is more dependant on the drying process than on the myoglobin oxidation of the tissue (Feldhusen, 1992). According to the results of various experimenters, this results in a decrease in colour lightness (Ledward, 1971; Feldhusen, 1992). In the course of the entire cooling (0–20 h), the lightness values increased in all experimental groups. Significant differences within the groups could not be established.

During the spray-chilling (0–4 h cooling time) the red- and yellow-values (a^*- and b^*-values) of the muscle surface decreased in parallel to the increased oxygenation (Fig. 3). In contrast, other experiments (Johansson, 1989; Feldhusen & Reinhard, 1994) and the control groups showed that the a^*-values increased during oxygenation to light red oxymyoglobin and decreased during oxidation to brown-gray metmyoglobin. In the control groups the a^*- and b^*-

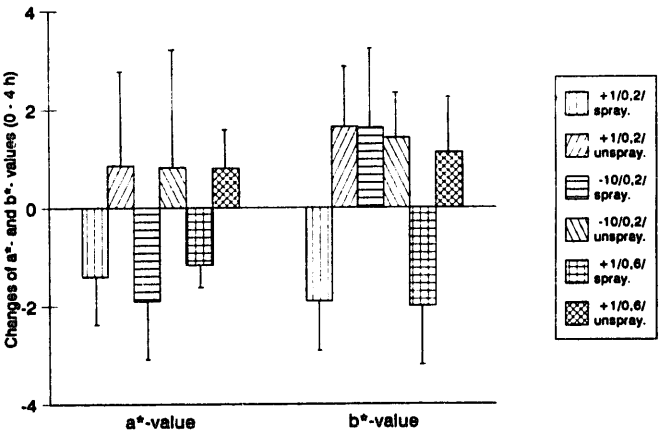

Fig. 3. Influence of spray-chilling conditions on the a^*- and b^*-values of the medial muscle surface during chilling ($\bar{x}$, $n = 5$).

values increased while a somewhat lower increase in oxymyoglobin was observed. These differences were significant ($P < 0{\cdot}05$). Perhaps they depend on the different reflection of light at the higher water contents (Swatland, 1992) in the sprayed muscle surface. Similar to the unsprayed control groups, the a^*-value of the sprayed groups increased with progressive dryness and increasing absolute myoglobin content during the course of the entire cooling of 0–20 h. Therefore no significant influence of spraying after 20 h chilling was found. The b^*-value of the ham musculature increased in the unsprayed swine halves from 0 to 4 h cooling time in parallel with the drying off of the meat surface. The combination of spray-chilling and fast-cooling conditions (experimental groups +1/0·2/spr. and +1/0·6/spr.) resulted in a decrease in the yellow-value within the spraying phase (Fig. 3). The increased moisture on the surface of the musculature of the sprayed carcasses was probably responsible for the decrease in the b^*-values, as experiments by Feldhusen (1994) showed.

The L^*-value of the *skin* decreased in nine of 10 cooling groups during cooling of up to 20 h (Fig. 2). The skin of the unsprayed control group darkened considerably in the first 4 h of cooling in contrast to the sprayed halves. The differences measured during the first 4 h cooling between the sprayed and the unsprayed groups did, however, not change. The skin of the sprayed halves was considerably lighter (2–8 units). The relative dry matter content of the skin increased in the sprayed experimental groups up to 20 h cooling time only by 2·4% at most in contrast to about 20% in the unsprayed control group. The drying of the skin during cooling led to a darkening of the carcass surface (Wirth *et al.*, 1975). The incident light was reflected and scattered more strongly by the damp skin of the carcass than by a dry skin surface (Ziolecki, 1967).

The colour of the *spinal spongiosa* was not influenced significantly by spraying during the 20 h cooling. This time of 20 h was presumably too short to induce any significant colour differences. The reported results show that a combination of spray-chilling and induced fast-cooling causes considerable changes in colour in the region of the spongiosa of exposed bones after a cooling for 1–2 days, which is possibly caused by an accelerated *post mortem* haemolysis.

CONCLUSIONS

A 4 h periodical spray-chilling treatment, in combination with fast-cooling conditions, caused initial changes in the colour values of the musculature, which disappeared during further cooling. The colour of the skin became lighter through spray-chilling. No influence on the colour of the spinal spongiosa during the 20 h cooling could be established.

A final evaluation of spray-chilling can only be made after intensive examinations of the colour changes of the spinal spongiosa during a longer cooling phase and of the bacteriological status of the carcass surfaces.

REFERENCES

Allen, D. M., Hunt, M. C., Luchiari Filho, A., Danler, R. J. & Goll, S. J. (1987). *J. Anim. Sci.*, **64**, 165.

Cornforth, D. P., Egbert, W. R. & Sisson, D. V. (1985). *J. Food Sci.*, **50**, 1021.

Feldhusen, F. (1993). *Fleischwirtsch*, **73**, 184.

Feldhusen, F. & Reinhard, H.-J. (1994). *Fleischwirtsch.*, **74**, 765.

Hunt, M. C. (1980). *Reciprocal Meat Conf. Proc.*, **33**, p. 41.

Johansson, G. (1989). *Proc. 35th Int. Congr. Meat Sci. Technol.*, Copenhagen, Denmark, p. 601.

Jones, S. D. M., Murray, A. C. & Robertson, W. M. (1988). *Can. Inst. Food Technol. J.*, **21**, 102.

Jones, S. D. M. & Robertson, W. M. (1988*a*). *Proc. 34th Int. Congr. Meat Sci. Techol.*, Brisbane, Australia, Part A, p. 236.

Jones, S. D. M. & Robertson, W. M. (1988*b*). *Meat Sci.*, **24**, 177.

Lanier, T. C., Charpenter, J. A. & Toledo, R. T. (1977). *J. Food Sci.*, **42**, 860.

Lauren, M. L., Hawrysh, Z. J., Jeremiah, L. E. & Hardin, R. T. (1990). *J. Food Sci.*, **55**, 1270.

Lebensmittel- und Bedarfsgegenständegesetz (1980). (L 06.00/3) Verlag Beuth, Berlin, Band 1/2, (L), Teil 2 (Lebensmittel- und Bedarfsgegenständegesetz, 1980).

Ledward, D. A. (1970). *J. Food Sci.*, **35**, 33.

Ledward, D. A. (1971). *J. Food Sci.*, **36**, 138.

Romans, J. R. & Norton, H. W. (1989). *Proc. 35th Int. Congr. Meat Sci. Technol.*, Kopenhagen, Denmark, p. 614.

Stewart, M. R., Hutchins, B. K., Zipser, M. W. & Watts, B. W. (1965). *J. Food Sci.*, **30**, 487.

Swatland, H. J. (1992). *Proc. 38th Int. Congr. Meat Sci. Technol.*, Clermont-Ferrand, France, p. 161.

Wirth, F., Leistner, L. & Rödel, W. (1975). *Fleischwirtsch.*, **55**, 1188.

Ziolecki, J. (1967). *Fleischwirtsch.*, **47**, 484.