PROCESSING AND PRODUCTS

The Effect of Holding Temperature on Live Shrink, Processing Yield, and Breast Meat Quality of Broiler Chickens

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ABSTRACT The effects of antemortem holding temperatures on live shrink, processing yields, and breast meat quality of broiler chickens were evaluated. A total of 462 broilers was reared to 45 d of age using conventional husbandry practices, removed from feed and water, and cooped 12 h prior to slaughter. During the 12-h feed withdrawal and holding time, the birds were held at 25, 29.5, or 34 C. Birds were individually weighed at cooping, prior to slaughter, and during processing to determine live shrink and processed carcass yields. The breast meat was removed at 2 or 24 h postmortem and was used to determine hot and cold boned meat pH, R-value, sarcomere length, meat color (lightness, redness, and yellowness), cooked yield, and shear value. The birds held at 34 C showed the significantly greatest live shrink, 5.7%, compared to those held at 29.5 or 25 C with 3.9 and 3.2% shrink, respectively. Birds held at 34 C exhibited significantly lower processed carcass yields based on initial catch weight, but when calculated using postshrink weights, there were no significant differences between treatment groups. For breast meat harvested at 2 h postmortem, the birds held at 25 C had higher R-values, redness, and yellowness values and lower cooked meat yield and shear values. For breast meat harvested at 24 h postmortem, the birds held at 25 C had higher pH, R-values, and redness. These results support earlier reports that holding conditions may dramatically effect live bird shrink and apparent yields (based on calculation denominator) but have relatively little effect on subsequent breast meat quality, regardless of postmortem deboning time.

(*Key words*: breast meat quality, broiler, holding temperature, live shrink, yield)

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INTRODUCTION

Environmental conditions during transport and holding of livestock have been shown to affect live shrink and subsequent meat quality. During the summer months, the poultry industry often experiences increased live shrink and excessive processed yield losses because birds respond to the increased temperature by decreasing feed intake and increasing panting, which alters water intake and body moisture loss profiles. Hale et al., (1980) and Holm and Fletcher (1997) reported greater live shrink of birds held at elevated temperatures (40 and 29 C, respectively) than birds held at lower temperatures (20 and 18 C, respectively). Because processing plant efficiency depends on bird uniformity, variations in flock responses to changes in environmental temperatures during catching, hauling, and holding can contribute to processing yield losses, reduced product uniformity, and decreased product quality.

Important meat quality parameters include pH, color, water-holding capacity (WHC), and tenderness. The pH of meat after slaughter is affected primarily by the postmortem conversion of muscle glycogen stores to lactic acid that accumulates in the muscle. Changes in muscle pH also directly affect color and WHC due to the pH effect on protein structure and subsequent hydration properties of the meat proteins. The rate of postmortem pH change is controlled by the degree of hormonal and contractile status of muscle immediately before and during slaughter (Monin and Ouali, 1992). It is assumed that antemortem temperature affects the postmortem metabolism of muscle and subsequent meat quality via adrenal or other physiological responses or simply by fatigue of the animals (Lambooij, 1999).

Previous research had focused on determining the effect of antemortem temperatures on meat quality. Wismer-Pedersen (1959) and Forrest et al. (1963) reported increased occurrence of quality defects in pork meat during summer and fall months when temperatures fluctuated the most. Sayre et al. (1963) reported that subjecting pigs to elevated temperature immediately before the slaughter induced a rapid rate of postmortem muscle

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Abbreviation Key: GLM = general linear models; NY = New York; RTC = ready to cook; PSE = pale, soft exudative; WHC = water-holding capacity.

glycolysis as indicated by a decline in muscle color intensity. In poultry, Woods and Richards (1975) reported an increased rate of postmortem glycolysis and prolonged glycolysis with heat and cold stress, respectively. Froning et al. (1978) and Holm and Fletcher (1997), working with turkeys and broiler chickens, respectively, reported lower pH and higher shear value from birds kept at elevated temperatures compared to birds held in cooler conditions. McKee and Sams (1997) observed that turkeys that were subjected to elevated temperatures prior to slaughter exhibited pale, soft, and exudative (PSE) meat characteristics.

In many of these previous studies, the differences in environmental temperatures required to induce cold or heat stress were more extreme than would occur during normal commercial conditions (Woods and Richards, 1975; Lee et al., 1976; Froning et al., 1978; Babji et al., 1982). Therefore, the objective of this study was to evaluate the effects of more moderate temperature changes between the housing temperature and holding temperatures that may be more indicative of actual commercial conditions, considering modern production practices, such as environmentally controlled houses and industry concentration in southern regions of the US. Broiler chickens were subjected to holding temperatures of 25, 29.5, and 34 C for 12 h prior to slaughter to determine effects on live shrink, processing carcass yield, and meat quality parameters of the breast meat removed at 2 or 24 h postmortem.

MATERIALS AND METHODS

Three independent experimental trials were conducted to determine the effect of holding temperature on live shrink, processing yields, and broiler breast meat quality. In each trial, approximately 210 1-d-old male broiler chicks were obtained from a commercial hatchery and were reared using conventional husbandry methods. Birds were housed on litter (wood shavings) in a single pen with access to feed and water ad libitum . The initial brooding temperature was maintained at 35 C for the first week, was gradually lowered to 29.5 C in the third week, and then was maintained until termination of the experiment.

At 45 d of age and 12 h prior to slaughter, feed and water were removed, and 180 birds were randomly caught, individually weighed (catch weight), wing-banded, and placed in transport coops (internal dimensions of $86 \times 57 \times 24$ cm), 10 birds to a coop. The 18 coops were divided into three groups and placed into one of three different holding rooms set at 24 C (cool), 29.5 C (control or normal), or 34 C (warm) for 12 h.

After the 12-h holding time, the coops were transported to a pilot processing facility (approximately 0.25 km) and were processed in six replicate batches with one coop per holding temperature per batch. Birds were removed from coops, individually weighed (dock weight), hung on shackles, stunned (two-stage electrical stunner,[2] 14 V, pulsed DC at approximately 500 Hz for 18 s, followed by 14 V, 60 Hz AC for 9 s), killed by hand using a conventional unilateral neck cut to sever the carotid artery and jugular vein, bled for 140 s, scalded at 55 C for 110 s, and picked for 36 s in a commercial in-line picker. Upon exiting the picker, head and feet were removed, carcasses individually weighed [New York (NY) dressed weight], and were then eviscerated, reweighed (shell weight), and chilled in a static ice and water mixture for 2 h. The individual processing weights and associated yield calculations are described in Table 1.

After chilling, half of the birds were deboned immediately (hot boned) and half were held packed on ice for 24 h before deboning (cold boned). For both the hot and cold deboned groups, the breast meat (pectoralis superficialis or pectoralis major) was removed from both sides of the carcass. One breast fillet was used for immediate determination of pH, R-value, and sarcomere length. The contralateral breast fillet was individually bagged and held at 2 C until 48 h postmortem for individual color determination and cooking prior to determining cooked meat yield and meat texture.

pH Measurement

The pH of one breast fillet per bird was determined using a modification of the iodoacetate method initially described by Jeacocke (1977). Approximately 2.5 g of breast meat was removed from the cranial end of each fillet, minced by hand, homogenized in 25 mL of a 5 m*M* iodoacetate solution with 150 m*M* potassium chloride for 30 s, and the pH of the homogenate was determined using a pH meter[3] calibrated at pH 4.0 and 7.0.

R-Value Determination

R-value, the ratio of adenosine to inosine nucleotides, was determined using the ratio of absorbance at 250 and 260 nm as described by Honikel and Fischer (1977). R-values were determined in duplicate on one breast fillet from each bird.

Sarcomere Length

Sarcomere length was determined using a modification of the laser diffraction method described by Cross et al. (1980). Crude homogenates of the breast samples were prepared by blending 2.5 g of muscle with a solution containing 150 m*M* KCl and 5 m*M* sodium iodoacetate. At least 15 readings were taken and averaged for each breast sample.

Color Measurement

The CIE (1978) system color profile of lightness (L*), redness (a*), and yellowness (b*) was measured on indi-

[2]Simmons model SF-7001, Simmons Engineering Co., Dallas, GA 30132.

[3]Model 2001 equipped with a model 1000 probe, Sentron Inc., Federal Way, WA 98003.

TABLE 1. Variables and descriptions for weights and yield calculations

Variable	Description
Catch weight (g)	Individual bird weight at catch (before feed withdrawal)
Dock weight (g)	Individual bird weight immediately prior to slaughter
NY dressed weight (g)	New York weight (bled, picked, head and feet off)
Shell weight (g)	Prechill eviscerated carcass weight without giblets or neck
RTC weight (g)	Ready-to-cook, chilled carcass weight
Breast fillet raw weight (g)	Raw breast weight
Breast fillet cooked weight (g)	Cooked breast weight
Live shrink (g)	Catch weight – dock weight
Live shrink (%)	(Live shrink (g)/catch weight) × 100
Live shrink per hour (%)	Live shrink (%)/12
NYD-1 (%)	(NY dressed weight/catch weight) × 100
NYD-2 (%)	(NY dressed weight/dock weight) × 100
Shell yield-1 (%)	(Shell weight/catch weight) × 100
Shell yield-2 (%)	(Shell weight/dock weight) × 100
Shell yield-3 (%)	(Shell weight/NY dressed weight) × 100
RTC-1 (%)	(RTC weight/catch weight) × 100
RTC-2 (%)	(RTC weight/dock weight) × 100
RTC-3 (%)	(RTC weight/NY dressed weight) × 100
Chill water uptake (g)	RTC weight – shell weight
Chill water uptake (%)	(Chill water uptake (g)/shell weight) × 100
Cooked yield (%)	(Cooked breast weight/raw breast weight) × 100

vidual fillets using a reflectance colorimeter.[4] Color was measured in triplicate on the cranial, medial surface (bone side) in an area free of obvious color defects (bruises, blood spots, or surface discolorations). Measurements were made on the medial surface to avoid breast fillet surface discolorations due to possible over-scalding.

Cooking Procedure

At 48 h postmortem, fillets from the hot and cold boned treatments were individually weighed and cooked in steam on aluminum trays at 95 C for 20 min. The fillets were then allowed to equilibrate to room temperature and were reweighed; cooked yield was determined as described in Table 1.

Shear Value Determination

Shear values were determined using an Instron Universal Testing Machine[5] equipped with an Allo-Kramer shear cell by using the procedure described by Papinaho and Fletcher (1996). A 25 mm diameter core was removed from the thickest part of each fillet and was weighed; the sample was sheared with the blades at a right angle to the fibers using a 500-kg load cell and cross head speed of 500 mm/min. Shear values are reported as kilograms of shear per gram of sample.

Statistical Analyses

Data were analyzed using the ANOVA option of the general linear models (GLM) procedure of SAS® software (SAS Institute, 1988). The model tested the main effects for treatment and replication, as well as the interaction term, using residual error. When the treatment by replication interaction term was significant, that error was used to determine treatment main effect significance. Means were separated using Duncan's multiple-range test option of the GLM procedure (SAS Institute, 1988) with the appropriate test error term as described above. The observations and calculated variables from catch weight through chilled weight were analyzed using the entire data set. Observations and calculated variables taken postchill were analyzed separately for hot and cold boned birds.

RESULTS AND DISCUSSION

The final number of birds processed and their average weights for Experimental Trials 1 to 3 were 144 (2,179 ± 20 g), 143 (2,254 ± 19 g), and 175 (1,919 ± 18 g), respectively. The data for the catch weights through shell yield determinations are summarized by holding treatment in Table 2. For those variables in which there was a significant treatment by replication interaction, the main effect of treatment was tested using the mean square error of treatment by replication interaction and were designated by footnote in the probability column of the table.

There were no significant treatment differences in catch weight, but following 12-h holding, the dock weights of birds held in the warm temperature were significantly less ($P = 0.0515$) than for birds held at the control or cool temperatures. Birds held in the warm temperature also exhibited a significantly greater live shrink compared to the control and cool treatment groups, with 5.67 versus 3.87 and 3.16% loss, respectively. These results are in general agreement with several previous reports. Holm and Fletcher (1997) reported similar results, even though shrink was determined on birds held over a wider range of temperatures (7, 18, and 29 C). Buhr et al., (1998) reported live shrink values of 5.21, 3.22, and 4.13% for broilers processed at 42, 44, and 48 d of age, respectively.

[4]Minolta Chroma Meter CR-300, Minolta Corp., Ramsey, NJ 07446.
[5]Instron Corp., Canton, MA 02021.

When shrink is reported on a per hour basis, the results are similar to those reported by several authors as compared and discussed by Warriss et al. (1999).

The birds from the warmer holding temperature exhibited significantly lower NY dressed and shell weights than the birds held in the control or cool temperatures, presumably as a result of the greater shrink loss. NY dressed yields were significantly less for the warm birds, compared to the control and cool birds, when calculated using catch weight. However, both control and warm birds had significantly lower NY dressed yields compared to the birds in cooler temperature but were not significantly different from each other when NY dressed yield was calculated using dock weight. A similar pattern was observed for carcass shell yields, with the significant differences in yields being dependent on the calculation base (catch weight, dock weight, or NY dressed weight). It is interesting that shell yield (comparable to a prechill processing plant yield) was not significantly different between treatments when calculated using either dock weight or NY dressed weight.

The results for ready-to-cook (RTC) yields, water uptake, and meat quality for both the 2 and 24 h deboned breast meat are presented in Tables 3 and 4, respectively. Regardless of chill time prior to deboning, the RTC weight and calculated yields were similar. The birds held at the different temperatures had significantly different RTC weights and lower RTC yields than the RTC yields calculated using the dock or NY dressed weights. Chill water uptake (g or %) was not affected by treatment. These results are similar to the shell yields in that other than effects on live weight, treatment had no effect on carcass yields or chill water uptake.

For the breast meat harvested at 2 h postmortem, there were no significant differences by treatment for muscle pH, sarcomere length, or lightness (L*). The breast meat from birds held at warm temperature had significantly lower values for redness (a*) and yellowness (b*) and higher shear value than breast meat from the control or cool temperatures. R-value was significantly higher for the breast meat from birds held in the cool temperature compared to those from the control and warm environments, which were not different from each other. Cooked yield for the breast meat from the warm environment was significantly greater than that for samples from the cool environment, but the control samples were not different from the warm or cool samples.

For the breast meat harvested at 24 h postmortem, no difference was found in pH, R-value, sarcomere length, L*, b*, cooked yield, or shear value among birds held at different holding temperatures. The only significant treatment effect was for a* values in which breast meat from the birds held in the warm temperature was less red than the meat from birds held in the control or cool temperatures.

The results for the RTC weights and yields for the 2 and 24 h deboning groups follow the same trends observed for the NY dressed and shell weights and yields. Birds held in the warm temperature had significantly lower RTC weights and RTC yield when calculated using the catch weight. However, when RTC yield was calculated using the dock or NY dressed weights, there were no significant treatment effects. There were also no significant treatment effects on absolute or percentage chill water uptake. These results agreed with Holm and Fletcher (1997) who reported that holding temperatures of 7, 18, and 29 C had no effect on chill water uptake.

Holding temperature effects on pH, sarcomere length, color, cooked yield, and texture were mixed between the two groups deboned at 2 or 24 h. For the birds deboned at 2 h postmortem, there were no significant effects on meat pH. However, birds held in the warm environment and deboned at 24 h postmortem had lower pH than those held at the cool or control temperature ($P = 0.0718$). These results are consistent with those presented previously by Babji et al. (1982), Holm and Fletcher (1997),

TABLE 2. Effect of antemortem holding temperatures of 25 C (cool), 29.5 C (control), and 34 C (warm) on catch weight, dock weight, live shrink, New York (NY) dressed weight and yields, and shell weight and yields (means ± SE)

	Treatment[2]			
Variable[1]	Cool	Control	Warm	*P*
Catch weight (g)	2,098 ± 20	2,139 ± 22	2,055 ± 26	0.1733[3]
Dock weight (g)	2,034 ± 20[a]	2,043 ± 21[a]	1,937 ± 24[b]	0.0515[3]
Live shrink (%)	3.16 ± 0.09[b]	3.87 ± 0.10[b]	5.67 ± 0.15[a]	0.0160[4]
Live shrink per hour (%/hr)	0.26 ± 0.01[b]	0.32 ± 0.01[b]	0.47 ± 0.01[a]	0.0160[4]
NYD weight (g)	1,754 ± 17[a]	1,767 ± 17[a]	1,665 ± 21[b]	0.0231[3]
NYD-1 yield[4] (%)	83.6 ± 0.1[a]	82.6 ± 0.1[a]	81.1 ± 0.2[b]	0.0063[4]
NYD-2 yield[5] (%)	86.4 ± 0.1[a]	86.0 ± 0.1[b]	86.0 ± 0.1[b]	0.0027[3]
Shell weight (g)	1,498 ± 15[a]	1,510 ± 16[a]	1,421 ± 18[b]	0.0197[3]
Shell yield-1 (%)	71.4 ± 0.12[a]	70.6 ± 0.1[ab]	69.2 ± 0.2[b]	0.0598[4]
Shell yield-2 (%)	73.7 ± 0.1	73.4 ± 0.1	73.4 ± 0.2	0.0690[3]
Shell yield-3 (%)	85.3 ± 0.1	85.4 ± 0.1	85.3 ± 0.1	0.9375[4]

[a,b]Means within a row followed by different superscript letters differ significantly ($P < 0.05$).

[1]See Table 1 for variable descriptions and methods of calculation.

[2]n = 462 (cool, n = 180; control n = 176; warm, n = 106).

[3]Significance determined using residual error.

[4]Significance determined using by replicate mean square error as the test statistic.

TABLE 3. Effect of antemortem holding temperatures of 25 C (cool), 29.5 C (control), and 34 C (warm) at 2 h postmortem deboned carcass ready-to-cook (RTC) weight and yields, chill water uptake and breast meat pH, R-value, sarcomere length, lightness (L*), redness (a*), yellowness (b*), cook yield, and shear value (means ± SE)

	Treatment[2]			
Variable[1]	Cool	Control	Warm	*P*
RTC weight (g)	1,543 ± 22[a]	1,553 ± 24[a]	1,455 ± 26[b]	0.0609[3]
RTC-1 yield (%)	73.3 ± 0.2[a]	72.4 ± 0.2[ab]	70.8 ± 0.3[b]	0.0518[4]
RTC-2 yield (%)	75.7 ± 0.2	75.3 ± 0.2	75.2 ± 0.2	0.4200[4]
RTC-3 yield (%)	87.6 ± 0.2	87.6 ± 0.2	87.6 ± 0.3	0.9216[3]
Chill water uptake weight (g)	41.3 ± 1.7	38.4 ± 1.5	38.8 ± 2.5	0.5198[3]
Chill water uptake yield (%)	2.78 ± 0.11	2.56 ± 0.10	2.81 ± 0.20	0.3918[3]
pH	6.15 ± 0.01	6.16 ± 0.01	6.18 ± 0.02	0.4886[3]
R-value	1.11 ± 0.01[a]	1.06 ± 0.01[b]	1.07 ± 0.03[b]	0.0103[3]
Sarcomere length (μm)	1.972 ± 0.004	1.957 ± 0.005	1.948 ± 0.007	0.1260[4]
L*	47.1 ± 0.2	46.8 ± 0.2	46.5 ± 0.3	0.3012[3]
a*	2.77 ± 0.14[a]	2.62 ± 0.12[a]	2.30 ± 0.14[b]	0.0320[3]
b*	8.66 ± 0.14[a]	8.57 ± 0.15[a]	8.02 ± 0.18[b]	0.0603[3]
Cook yield (%)	71.4 ± 0.4[b]	72.1 ± 0.3[ab]	73.0 ± 0.4[a]	0.0132[3]
Shear value (kg/g)	6.05 ± 0.22[b]	6.86 ± 0.31[b]	7.94 ± 0.54[a]	0.0002[3]

[a,b]Means within a row followed by different superscript letters differ significantly ($P < 0.05$).

[1]See Table 1 for variable descriptions and methods of calculation.

[2]n = 241 (cool, n = 90; control n = 87; warm, n = 54).

[3]Significance determined using residual error.

[4]Significance determined using by replicate mean square error as the test statistic.

and McKee and Sams (1997), who all found that birds held in cooler temperatures had significantly higher terminal pH values than birds subjected to higher temperatures. McKee and Sams (1997) also showed similar results for muscle pH values measured at 2 h postmortem.

The R-values measured on breast meat removed at 2 h postmortem were observed to be significantly higher in the cool treatment, although no significant differences were found in R-values measured on breast fillets removed at 24 h postmortem. These data are not in agreement with those of McKee and Sams (1997) who reported that heat stress increased R-values measured at 15 min and 2 and 24 h, respectively, in turkey breast meat.

There were no treatment effects on sarcomere lengths measured on breast meat removed 2 or 24 h postmortem. For breast meat color, the results were mixed. No difference in lightness (L*) was detected among treatments regardless of deboning time. These results agree with Holm and Fletcher (1997) but not with results reported by Froning et al. (1978) and McKee and Sams (1997), who observed at 24 h postmortem, darker and lighter breast meat, respectively, from heat-stressed turkeys. Breast

TABLE 4. Effect of antemortem holding temperatures of 25 C (cool), 29.5 C (control), and 34 C (warm) at 24 h postmortem deboned carcass ready-to-cook (RTC) weight and yields, chill water uptake and breast meat pH, R-value, sarcomere length, lightness (L*), redness (a*), yellowness (b*), cook yield, and shear value (means ± SE)

	Treatment[2]			
Variable[1]	Cool	Control	Warm	*P*
RTC weight (g)	1,580 ± 22[a]	1,591 ± 22[a]	1,508 ± 25[b]	0.0623[3]
RTC-1 yield (%)	75.6 ± 0.2[a]	74.6 ± 0.2[b]	73.5 ± 0.3[c]	0.0001[3]
RTC-2 yield (%)	77.9 ± 0.2	77.6 ± 0.2	77.8 ± 0.2	0.3679[3]
RTC-3 yield (%)	90.4 ± 0.2	90.4 ± 0.2	90.3 ± 0.2	0.9905[3]
Chill water uptake weight (g)	87.1 ± 2.1	85.7 ± 2.2	81.6 ± 2.8	0.8544[3]
Chill water uptake yield (%)	5.84 ± 0.12	5.72 ± 0.14	5.74 ± 0.19	0.6837[3]
pH	5.95 ± 0.04	5.96 ± 0.01	5.86 ± 0.02	0.0718[3]
R-value	1.29 ± 0.02	1.27 ± 0.02	1.23 ± 0.02	0.1170[3]
Sarcomere length (μm)	2.008 ± 0.002	2.007 ± 0.002	2.006 ± 0.002	0.1099[3]
L*	47.8 ± 0.3	48.0 ± 0.3	48.6 ± 0.4	0.2812[3]
a*	3.04 ± 0.11[a]	2.84 ± 0.11[a]	2.48 ± 0.12[b]	0.0058[3]
b*	8.66 ± 0.13	8.85 ± 0.16	8.98 ± 0.24	0.0964[3]
Cook yield (%)	70.7 ± 0.3	70.6 ± 0.3	71.2 ± 0.4	0.3436[3]
Shear value (kg/g)	4.59 ± 0.18	4.87 ± 0.19	4.91 ± 0.21	0.5441[4]

[a–c]Means within a row followed by different superscript letters differ significantly ($P < 0.05$).

[1]See Table 1 for variable descriptions and methods of calculation.

[2]n = 241 (cool, n = 90; control n = 89; warm, n = 58).

[3]Significance determined using residual error.

[4]Significance determined using by replicate mean square error as the test statistic.

meat from birds held in the warmer temperature exhibited significantly less redness (a*) at 2 and 24 h deboning times and less yellowness (b*) values only for the 2-h deboning time. Although it appears that holding temperatures affect breast meat color in this study, the effects appear inconsistent when compared to previous studies.

The breast meat harvested at 2 h postmortem from birds held in the warmer temperature had significantly greater cooked yield compared to the breast meat from birds held in the cool environment but was not different from the control birds. There were no significant differences in breast meat cooked yield from the 24-h deboned group. Holm and Fletcher (1997) reported a higher cooked yield for the breast meat from birds held in warmer temperatures.

For meat toughness, the warm holding temperature resulted in significantly greater shear values in the 2-h deboned samples only. These results are in agreement with studies that have indicated that birds held in warmer temperature yield tougher meat than that from birds held at cooler temperatures (Simpson and Goodwin, 1975; Lee et al., 1976; Froning et al., 1978; Holm and Fletcher, 1997).

These results demonstrate that warm holding temperatures (34 C), compared to control housing temperatures at 29.5 C, increase live bird shrink and decrease associated carcass yields calculated using catch weight. However, after live shrink and using dock or NY dressed weights, holding temperature has no effect on subsequent carcass yield parameters. There appears to be some effect of holding temperature on selected meat quality parameters, but these effects are not always consistent or necessarily dramatic (may be of relatively little practical or industry importance). There also appears to be a minor interactive effect of postmortem handling with holding temperature.

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REFERNCES

Babji, A. S., G. W. Froning, and D. A. Ngoka, 1982. The effect of preslaughter environmental temperature in the presence of electrolyte treatment on turkey meat quality. Poultry Sci. 61:2385–2389.

Buhr, R. J., J. K. Northcutt, C. E. Lyon, and G. N. Rowland, 1998. Influence of time off feed on broiler viscera weight, diameter, and shear. Poultry Sci. 77:758–764.

C.I.E., 1978. Internatonal Commission on Illumination, Recommendations on Uniform Color Spaces, Color Difference Equations, Psycometric Color Terms. Supplement No. 15 C.I.E. Publication No. 15 (E-1.3.1) 1971/(TO-1.3). Bureau Central de la C.I.E., Paris, France.

Cross, H. R., R. L. West, and T. R. Dutson, 1980. Comparison of methods for measuring sarcomere length in beef semitendonosus muscle. Meat Sci. 5:261–266.

Forrest, J. C., R. F. Gundlach, and E. J. Briskey, 1963. A preliminary survey of the variation in certain pork ham muscle characteristics. Pages 81–91 *in*: Proceedings of the Research Council of American Meat International Foundation. Univ. of Chicago, Chicago, IL.

Froning, G. W., A. S. Babji, and F. B. Mather, 1978. The effect of preslaughter temperature, stress, struggle and anesthetization on color and textural characteristics of turkey muscle. Poultry Sci. 57:630–633.

Hale, K. K., Jr., G. P. Birrenkott, and V. C. Waldrop, 1980. Effects of environment on processing and cooked yields of turkeys. Poultry Sci. 59:1616.

Holm, C. G., and D. L. Fletcher, 1997. Antemortem holding temperatures and broiler breast meat quality. J. Appl. Poultry Res. 6:180–184.

Honikel, K. O., and C. Fischer, 1977. A rapid method for the detection of PSE and DFD porcine muscles. J. Food Sci. 42:1633–1636.

Jeacocke, R. E., 1977. Continuous measurement of the pH of beef muscle in intact beef carcasses. J. Food Technol. 12:375–386.

Lambooij, E., 1999. Handling of poultry before slaughter: some aspects of welfare and meat quality. Pages 311–323 *in*: Proceedings of the XIV European Symposium on the Quality of Poultry Meat, Bologna, Italy.

Lee, Y. B., G. L. Hargus, E. C. Hagberg, and R. H. Forsythe, 1976. Effect of antemortem environmental temperatures on postmortem glycolysis and tenderness in excised broiler breast muscle. J. Food Sci. 41:1466–1469.

McKee, S. R., and A. R. Sams, 1997. The effect of seasonal heat stress on rigor development and the incidence of pale, exudative turkey meat. Poultry Sci. 76:1616–1620.

Monin, G., and A. Ouali, 1992. Muscle differentiation and meat quality. Pages 89–159 *in*: Development in Meat Science. R. A. Lawrie, ed. Elsevier Appl. Sci., London, UK.

Papinaho, P. A., and D. L. Fletcher, 1996. the effect of stunning amperage and deboning time on early rigor development and breast meat quality of broilers. Poultry Sci. 75:672–676.

SAS Institute, 1988. SAS®/STAT Guide for Personal Computers. Version 6.03 Edition. SAS Institute Inc., Cary, NC.

Sayre, R.N.E., E. J. Briskey, and W. G. Hoekstra, 1963. Alteration of postmortem changes in porcine muscle by preslaughter heat treatment and diet modification. J. Food Sci. 28:292–297.

Simpson, M. D., and T. L. Goodwin, 1975. Tenderness of broilers as affected by processing plant and seasons of the year. Poultry Sci. 54:275–279.

Warriss, P. D., L. J. Wilkins, and T. G. Knowles, 1999. The influence of ante-mortem handling on poultry meat quality. Pages 217–230 *in*: Poultry Meat Science, R. I. Richardson and G. C. Mead, ed. CABI Publishing, Oxfordshire, UK.

Wismer-Pedersen, T., 1959. Quality of pork in relation to rate of pH change post-mortem. Food Res. 24:711–727.

Wood, D. F., and J. F. Richards, 1975. Effect of some antemortem stressors on postmortem aspects of chicken broiler pectoralis muscle. Poultry Sci. 54:528–531.