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EFFECT OF ELEVATED AIR TEMPERATURE ON SOME QUALITY PARAMETERS OF BROILER CHICKEN MEAT*

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Abstract

The aim of the study was to determine the effect of elevated air temperature in the first period of rearing broiler chickens from two commercial lines on selected quality parameters of their meat. Day-old Ross 308 and Hubbard Flex broiler chickens were assigned to 4 groups. Groups I (Ross 308) and II (Hubbard Flex) were kept under standard thermal conditions throughout rearing, and groups III (Ross 308) and IV (Hubbard Flex) were exposed to 10°C higher than recommended air temperature from 1 to 21 days of rearing. Simplified carcass analysis was performed at 42 days of the experiment. Meat pH was measured 15 min postmortem and 24 h after carcass chilling. Carcass colour and water holding capacity of meat were also determined. It was concluded from the results obtained that heat stress applied in the study decreased the pH of breast muscles, measured 15 min postmortem in broiler chickens from both commercial lines, which was probably associated with a tendency for lower water holding capacity of meat. It can thus be presumed that elevated air temperature in the first period of growth may negatively affect the quality of meat. Elevated air temperature did not have an adverse effect on the dissection results of broilers. The origin of birds influenced most dissection parameters, pH_{15} of breast muscles and broiler carcass colour. The dissection results indicate, however, that the body's reaction to heat stress may vary according to the origin of chickens.

Key words: broiler chickens, commercial line, meat quality, heat stress

High air temperature in broiler houses is recognized as one of the main factors negatively influencing avian productivity (Lu et al., 2007) and meat quality (Akşit et al., 2006; Wang et al., 2009). McKee and Sams (1997) report that heat-stressed birds are prone to disturbances in muscle energy metabolism, with poultry breast muscles that are the site of glycolytic metabolism being particularly susceptible (Sandercock et al., 2001). These authors report that heat stress leads to acid-base changes in blood, affects postmortem glycogen levels in muscle and decreases pH of

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meat. The initial muscle pH determines physicochemical traits of meat such as water holding capacity, colour, thermal drip and tenderness of heat-treated meat (Young et al., 2004; Akşit et al., 2006; Wang et al., 2009). Many authors state that decreased initial pH of breast muscles is an indicator of PSE meat (Debut et al., 2003; Barbut, 2009; Smith and Northcutt, 2009), which is detrimental in economic terms for the poultry industry (Barbut, 2009). The decrease in pH value is paralleled by a reduction in water holding capacity and the meat has a lighter colour (McKee and Sams, 1997; Bianchi et al., 2006; Lu et al., 2007; Wang et al., 2009). Petracci et al. (2004) observed lighter breast muscles (L*) and lower redness (a*) and yellowness (b*) in broiler chickens from the summer production cycles compared to those from the winter cycles. Yalçin et al. (2005) showed lower pH values of the meat from broilers reared at high air temperatures.

The quality of broiler chicken meat may also depend on the origin of birds (Berri et al., 2001; Debut et al., 2003).

Recent genetic selection of broiler chickens for increased rate of growth has made them more sensitive to environmental influences, including high air temperature (Lu et al., 2007). However, Campo et al. (2008) claim that stress susceptibility may be genetically determined.

Therefore, the objective of this study was to determine the effect of elevated air temperature in the first period of growth of broiler chickens from two commercial lines on selected quality parameters of meat.

Material and methods

The experiment involved 720 broiler chickens from two commercial lines Ross 308 (360 birds) and Hubbard Flex (360 birds). After weighing and tagging on the first day of life, chicks were assigned to 4 groups, each of which had 12 subgroups with a stocking density of 15 birds/m^2:

Group I – Ross 308 broilers kept throughout rearing under standard thermal conditions (Regulation of the Ministry of Agriculture and Rural Development of 2 Sept. 2003, Journal of Laws 03.167.1629 with later amendments),

Group II – Hubbard Flex broilers kept throughout rearing under standard thermal conditions (Regulation of the Ministry of Agriculture and Rural Development of 2 Sept. 2003, Journal of Laws 03.167.1629 with later amendments),

Group III – Ross 308 broilers exposed in the rearing area from 1 to 21 days of age to 10°C higher than recommended temperature (41°C at one day of age was gradually decreased to 35°C on day 21 of rearing),

Group IV – Hubbard Flex broilers exposed in the rearing area from 1 to 21 days of age to 10°C higher than recommended temperature (41°C at one day of age was gradually decreased to 35°C on day 21 of rearing).

Chickens were reared to 21 days of age in 6-tier batteries of heated cages with electronic temperature control and until 42 days of age in 4-tier batteries of unheated cages. Groups III and IV were located in a separated, air-conditioned room with an

electronically controlled heater. All the groups had the same environmental (air humidity, lighting regime) and feeding conditions.

Chickens were fed *ad libitum* diets: starter diet until 3 weeks (3083 kcal ME, 21.77% CP), grower diet from 4 to 5 weeks (3005 kcal ME, 19.97% CP), and finisher diet at 6 weeks of age (3004 kcal ME, 18.65% CP), all based on concentrates. Birds had free access to water drinkers at all times.

At 42 days of the experiment, 20 chickens with close to average body weight were selected from each group. After slaughter and chilling, they were subjected to simplified dissection, which included carcass weight with giblets before chilling, carcass weight with and without giblets after chilling, weight of giblets, breast muscles and leg muscles, weight of abdominal fat in carcass in relation to carcass weight with giblets and in relation to dressing percentage with and without giblets. pH of meat was measured 15 min postmortem (pH_{15}) and 24 h after carcass chilling (pH_{24}) using a CyberScan 10 pH meter and EC-FG 73905 electrode. Carcass colour was determined with a Minolta CR 310 reflectance colorimeter. Water holding capacity of meat was determined according to the method described by Grau and Hamm (1953).

The results were analysed statistically by two-way analysis of variance and significant differences were estimated with Duncan's test using Statgraphics Plus 6.0 software.

Results

Table 1 presents the slaughter results of 42-day-old broiler chickens. Comparison of Ross 308 and Hubbard Flex broilers maintained under standard conditions throughout rearing showed that dressing percentage, both with and without giblets, was significantly higher in broilers from the latter commercial line. Hubbard Flex broilers were also characterized by a lower percentage of giblets compared to Ross 308 birds ($P \leq 0.01$). When analysing the slaughter results of birds maintained at elevated air temperature to 21 days of the experiment, a highly significant difference was only found for breast muscle percentage. Ross 308 broilers reared under standard temperature conditions throughout the experiment were characterized by lower dressing percentage with giblets ($P \leq 0.05$), lower dressing percentage without giblets ($p \leq 0.01$), and higher giblets percentage ($P \leq 0.01$) compared to broilers of the same line exposed to elevated air temperature in the first period of growth.

The origin of birds had a significant effect on the pH of breast muscles 15 min postmortem (Table 2). Ross 308 broilers had a higher pH_{15} of breast muscles compared to Hubbard Flex chickens ($P \leq 0.05$) regardless of thermal rearing conditions. The thermal factor significantly reduced the pH_{15} of breast muscles in broilers of both lines but had no effect on the other pH values of chicken muscles.

Water holding capacity values are presented in Table 3. Breast and leg muscles of broilers from both commercial lines were characterized by similar water holding capacity ($P \geq 0.05$). Comparison of broiler chickens reared under different thermal conditions revealed a highly significant difference in the water holding capacity of leg muscles between Hubbard Flex chickens from groups II and IV.

Table 1. Slaughter results (%)

Item	Group				SEM	Commercial line (A)	Temperature (B)	A × B
	Standard temperature conditions		Elevated temperature to 21 days of growth					
	I	II	III	IV				
	Ross 308	Hubbard Flex	Ross 308	Hubbard Flex				
Dressing percentage with giblets	74.82 Ax	76.80 B	76.15 y	76.50	0.41	≤0.01	≤0.05	≤0.05
Dressing percentage without giblets	71.09 AX	73.31 B	72.71 Y	72.97	0.42	≤0.01	≤0.01	≤0.05
Breast muscles	24.60	23.96	24.86 B	23.42 A	0.35	≤0.01	NS	NS
Leg muscles	20.80	21.31	20.15	20.69	0.33	NS	NS	NS
Bones	5.36	5.38	5.50	5.34	0.15	NS	NS	NS
Fat	2.89	2.49	2.65	2.39	0.16	NS	NS	NS
Giblets	4.96 BX	4.57 A	4.52 Y	4.61	0.08	≤0.01	≤0.01	≤0.01

A, B, a, b – significant differences between broilers reared under the same temperature conditions.
X, Y, x, y – significant differences between broilers of the same commercial line reared under different temperature conditions.
a, b, x, y – values in rows with different letters differ significantly (P≤0.05).
A, B, X, Y – values in rows with different letters differ highly significantly (P≤0.01).

Table 2. pH measurements of breast and leg muscles

Item	pH	Group				SEM	Commercial line (A)	Temperature (B)	A × B
		Standard temperature conditions		Elevated temperature to 21 days of growth					
		I	II	III	IV				
		Ross 308	Hubbard Flex	Ross 308	Hubbard Flex				
Breast	15 min	6.41 a x	6.24 b x	6.25 b y	6.08 a y	0.05	≤0.05	≤0.05	NS
	24 h	5.75	5.72	5.76	5.72	0.06	NS	NS	NS
Leg	15 min	6.32	6.31	6.26	6.24	0.02	NS	NS	NS
	24 h	6.13	6.17	6.18	6.14	0.05	NS	NS	NS

a, b – significant differences between broilers reared under the same temperature conditions.
x, y – significant differences between broilers of the same commercial line reared under different temperature conditions.
a, b, x, y – values in rows with different letters differ significantly (P≤0.05).

Table 3. Water holding capacity (%)

Item	Group				SEM	Commercial line (A)	Temperature (B)	AxB
	Standard temperature conditions		Elevated temperature to 21 days of growth					
	I	II	III	IV				
	Ross 308	Hubbard Flex	Ross 308	Hubbard Flex				
Breast	19.21	21.34	18.58	19.32	1.20	NS	NS	NS
Leg	18.28	19.10 X	15.09	14.23Y	1.12	NS	≤0.01	NS

X, Y – significant differences between broilers of the same commercial line reared under different temperature conditions.
X, Y – values in rows with different letters differ highly significantly (P≤0.01).

Table 4. Carcass colour of 42-day-old broiler chickens

Item	Group				SEM	Commercial line (A)	Temperature (B)	A × B
	Standard temperature conditions		Elevated temperature to 21 days of growth					
	I	II	III	IV				
	Ross 308	Hubbard Flex	Ross 308	Hubbard Flex				
L*	68.10	71.10	65.30 b	71.05 a	2.35	<0.05	NS	NS
a*	8.40 a	7.60 b	8.10	7.90	0.21	<0.05	NS	NS
b*	9.15 A X	6.15 B	7.80 A Y	6.40 B	0.33	<0.01	<0.01	<0.05

A, B, a, b – significant differences between broilers reared under the same temperature conditions.
X, Y, x, y – significant differences between broilers of the same commercial line reared under different temperature conditions.
a, b, x, y – values in rows with different letters differ significantly ($P \leq 0.05$).
A, B, X, Y – values in rows with different letters differ highly significantly ($P \leq 0.01$).

Origin influenced carcass colour in 42-day-old broilers. Comparison of broilers reared under standard temperature conditions showed lower a* and b* values for the carcasses of Ross 308 compared to Hubbard Flex broilers at $P \leq 0.05$ and $P \leq 0.01$, respectively. Considering commercial lines maintained at elevated air temperature to 21 days, a significant difference was observed between Ross 308 and Hubbard Flex chickens for L* values and a highly significant difference for b* values of the carcass. Elevated air temperature decreased the b* value of Ross 308 broiler carcasses by 1.35 ($P \leq 0.01$).

Discussion

Reduced dressing percentage is one of the consequences of exposing birds to high air temperature (Sokołowicz et al., 1996). However, in our study Ross 308 broilers maintained at 10°C higher than recommended temperature in the first period of growth showed better dressing percentage, both with ($P \leq 0.05$) and without giblets ($P \leq 0.01$). Likewise, Lu et al. (2007) found higher dressing percentage in broilers maintained at higher temperature compared to birds kept under standard temperature conditions. Different results were obtained in a study by Sosnówka-Czajka et al. (2005) in which heat stress applied from 18 to 21 days of age had no effect on dissection results of broiler chickens.

In the present experiment, the thermal factor had no impact on the dissection results of Hubbard Flex broilers. It can therefore be concluded that Ross 308 and Hubbard Flex chickens respond differently to elevated air temperature in terms of dressing percentage. Likewise, Lu et al. (2007) showed different effects of heat stress on the dressing percentage of chickens of different origin.

The level of pH is one of the more important parameters determining the sensory and technological quality of meat (El Rammouz et al., 2004). In our study, the thermal factor lowered the pH_{15} of breast muscles in broiler chickens from both commercial lines. This possibly indicates that elevated air temperature is a strong stressor that may adversely affect muscle acidity even when applied in the first period of growth. Also Wang et al. (2009) found the pH_{30min} of breast muscles to decrease significantly in broiler chickens exposed to high ambient temperature for 1 to 5 h at 30 days of growth compared to birds maintained under standard temperature conditions. Meanwhile, Akşit et al. (2006) found lower pH_{24} values in Ross 308 broilers maintained at 34°C from 3 to 7 weeks of age compared to the control group. Similarly, Dai et al. (2009) reported lower pH_{24} values of breast muscles from broilers exposed to elevated air temperature compared to the control group. However, in our study the thermal factor had no effect on the pH_{24} of breast muscles in either Ross 308 or Hubbard Flex chickens. Meanwhile, Lu et al. (2007) and Sosnówka-Czajka et al. (2005, 2006) showed no effect of heat stress on lowering the pH of breast muscle in broiler chickens at both 15 min and 24 h postmortem.

Another important parameter that determines the processing suitability of meat is its water holding capacity, which is related to the pH and colour of meat (Dai et al.,

2009; Akşit, 2006; Warriss, 2006). Dai et al. (2009) and Wang et al. (2009) showed that water holding capacity in broiler chickens exposed to elevated air temperature decreased when compared with the control group, which may adversely affect further technological processing of meat (Richardson, 2004).

In the present study, rearing broiler chickens at 10°C higher temperature until 21 days of age was associated with a tendency for lower water holding capacity of breast muscles in broiler chickens of both commercial lines. In the case of leg muscles, water holding capacity in Hubbard Flex broilers was 4.87% lower while Ross 308 chickens only showed a tendency for lower water holding capacity as a result of the thermal factor.

The literature reports that lower pH values are associated with lighter meat colour (Akşit, 2006; Lu et al., 2007), but our study failed to confirm this relationship and no changes were found in the L* values of the carcasses from broilers exposed to elevated air temperature despite the fact that they were characterized by lower initial pH. According to McKee and Sams (1997), chronic heat stress increases muscle lightness, whereas Sandercock et al. (2001) report that acute heat stress has no impact on the colour of breast muscles from broiler chickens. Meanwhile, Dai et al. (2009) showed high ambient temperature to increase L* and b* values and decrease a* value. In our study, elevated air temperature in the first period of growth only had an effect on lowering the b* value of carcasses from Ross 308 broilers.

The quality of broiler meat is also influenced to a large extent by the origin of birds (Berri et al., 2001; Debut et al., 2003). In our study, bird origin had an effect on the dressing percentage of broilers and on the proportion of breast muscles and giblets in the carcass. Better dressing percentage and lower proportion of giblets in the carcass were found in Hubbard Flex broilers compared to Ross 308 chickens, which were reared under standard temperature conditions. Ross 308 broilers had a higher percentage of breast muscles in the carcass in relation to the other commercial line, which was particularly noticeable in the groups exposed to elevated air temperature in the first period of growth.

Sosnówka-Czajka et al. (2005) reported a slight effect of origin on the acidity and colour of broiler meat. Similar results were obtained by Bianchi et al. (2006), who found no differences in meat colour between Ross 508 and Cobb 500 broilers. Meanwhile, Debut et al. (2003) demonstrated differences in the pH_{15} of breast muscles from chickens of two genetic groups. Also Berri et al. (2001) found differences in the initial pH of breast muscles between 5 genetic groups of broiler chickens. In our study too, the origin had an impact on the pH_{15} of breast muscles from experimental chickens. Ross 308 broilers were characterized by lower pH_{15} of breast muscles regardless of thermal rearing conditions compared to Hubbard Flex chickens. In our experiment, bird origin also influenced carcass colour. The carcasses of Ross 308 broilers were characterized by lower L* and higher a* and b* values compared to Hubbard Flex chickens, which Kirkpinar et al. (2001) claim is evidence of more beneficial carcass colour.

It was concluded from the results obtained that heat stress applied in the study decreased the pH of breast muscles, measured 15 min postmortem in broiler chickens from both commercial lines, which was probably associated with a tendency

for lower water holding capacity of meat. It can thus be presumed that elevated air temperature in the first period of growth may negatively affect the quality of meat. Elevated air temperature did not have an adverse effect on the dissection results of broilers. The origin of birds influenced most dissection parameters, pH_{15} of breast muscles and broiler carcass colour. The dissection results indicate, however, that the body's reaction to heat stress may vary according to the origin of chickens.

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Wpływ podwyższonej temperatury powietrza na kształtowanie się niektórych parametrów jakościowych mięsa kurcząt brojlerów

STRESZCZENIE

Celem badań było określenie wpływu podwyższonej temperatury powietrza w pierwszym okresie odchowu kurcząt brojlerów dwóch linii towarowych na wybrane parametry jakościowe mięsa.

Jednodniowe kurczęta brojlery Ross 308 i Hubbard Flex przydzielono do 4 grup. W grupie I i II utrzymywano odpowiednio: kurczęta brojlery Ross 308 i Hubbard Flex, przez cały okres odchowu zachowując standardowe warunki termiczne. W grupie III i IV również utrzymywano odpowiednio: kurczęta brojlery Ross 308 i Hubbard Flex, ale od 1. do 21. dnia odchowu ptaki poddano działaniu podwyższonej o 10°C temperatury powietrza w stosunku do zalecanej. W 42. dniu doświadczenia przeprowadzono uproszczoną analizę rzeźną. Wykonano także pomiar pH mięsa w 15 minucie po uboju i w 24 godzinie po schłodzeniu tuszki, określono barwę tuszki oraz oznaczono wodochłonność mięsa.

Na podstawie uzyskanych wyników stwierdzono, że zastosowany w badaniach własnych stres cieplny obniżył pH mięśni piersiowych kurcząt brojlerów obydwu linii towarowych mierzone w 15 minucie po uboju, co wiązało się prawdopodobnie z tendencją do mniejszej zdolności mięsa do wiązania wody. Można zatem przypuszczać, iż podwyższona temperatura powietrza w pierwszym okresie odchowu kurcząt brojlerów może mieć negatywny wpływ na jakość mięsa. Podwyższona temperatura powietrza nie wpłynęła natomiast negatywnie na wyniki analizy rzeźnej kurcząt brojlerów. Pochodzenie ptaków wpłynęło na większość parametrów analizy rzeźnej, pH_{15} mięśni piersiowych oraz na barwę tuszki kurcząt brojlerów. Wyniki analizy rzeźnej wskazują jednak, że reakcja organizmu kurcząt na stres cieplny może być różna, w zależności od pochodzenia