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Transport stress impact on postmortem metabolisms of turkey meat quality

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Abstract - The present study was designed to evaluate the effect of preslaughter transport time on meat turkey quality. Three hundred Hybride male turkeys (16 weeks aged) were divided into three groups and were transported in coops on trailer during three different terms: 15 min to 30 min, 1h15 to 1h30 min and 2h to 2h30 min. A total of birds were slaughtered on industrial processing line after 2h recovery-time. The pectoralis *major* muscle samples were collected for pH (20 min, 3h, 6h, 24 h), color values L*, a* and b*, drip loss, cook loss and shear force. Transport time affected the kinetics of post-mortem pH decline ($p<0.0001$). A long-term transported turkeys decreased the pH_{20min} and the rate of pH decline ($p<0.0001$). Nevertheless, the turkeys were transported for 2h to 2h30 min had the lowest pH at 20 min and the highest pH muscle at 24h. However, the color values L*, a* and b* were not affected by transport stress. A long-term transported contributed to decreased drip loss ($p<0.05$) and high levels to cook loss ($p<0.0001$). Moreover, there were significant differences in water holding capacity at day 3 post-mortem ($p<0.0001$). Furthermore, a long term of transport increased significantly the shear force ($P < 0.0001$). These results suggest that transporting turkeys for long-term before processing may induce pale, soft and exudative meat (PSE).

Keywords: transport, turkey, meat quality, postmortem metabolism, PSE.

1. Introduction

Meat quality of domesticated animals can be affected by several ante-mortem stress factors (Apple et al. 1995; Kannan et al. 1997), such as preslaughter transportation. The pale, soft, and exudative (PSE) meat is more associated with short-term stress. It has been suggested that short term pre-slaughter stress results in an acceleration of muscle metabolism that continues at a high rate when the animal is slaughtered. This acceleration leads to a fast decline in muscle pH early postmortem while carcass temperatures are still high, which results in protein denaturation. This denaturation of proteins can result in meat with pale color, poor water-holding capacity, and poor texture. DFD meat is associated with long-term stress before slaughter. The stress can cause a depletion in muscle glycogen resulting in higher postmortem muscle pH because of the prevention of glycolysis by elimination of its substrate (Hedrick et al. 1989; Gregory 1994; Lawrie 1998). Meat with this condition is dark in color, has a firm texture, and dry appearance or high water-holding capacity (Lawrie 1998). Transport alters both the metabolism and psychological state of animals, which may produce undesirable changes in meat quality (Owens and Sams 2000; Perez et al. 2002a; Leheska et al. 2003). The transportation process can be stressful to the birds. Researchers have found that transportation induces stress in swine and poultry, as indicated by increased levels of β-endorphin, corticosterone, cortisol, and creatine phosphorkinase (Szilagyi et al. 1981; Freeman et al. 1984; Bilgili et al. 1994; Brown et al. 1998). Although there is much research on the effects of transportation on the physiology of poultry and swine animals, there is limited information on the effects of transportation on poultry meat quality (Owens and Sams 2000). Because previous research has shown that transportation is a stressor to turkeys and broilers, future research is needed to evaluate various transportation times (<3 h) to determine the effects on meat quality. Therefore, the objective of this study was to evaluate the effect of preslaughter transport on postmortem metabolism meat of market-aged turkeys.

2. Material and Methods

Birds aged 16 weeks, weighed approximately 12 kg, 300 turkeys from Hybride line were randomly chosen from within a flock, and slaughtered on a commercial processing line. Birds were divided into three groups and were transported in coops on trailer during three different terms: The T15 group, birds were transported during 15 min to 30 min; Turkeys from T90 group were transported for 1h15 to 1h30 and the third group (T120) was transported during 2h to 2h30 min. A total of birds were slaughtered with a constant postprandial delay to slaughter (10h), to avoid the confounding between the effects of the experimental treatments and those of fasting duration. All birds were slaughtered after 2h recovery-time. The pectoralis *major* muscle samples were collected for pH (20-30 min, 3h, 6h, 24 h), color values L*, a* and b*(24h). The meat samples was conserved at 4° C during three days postmortem to measure drip loss, cook loss, water holding capacity and shear force.

2.1. pH

The initial pH (pH_{20min}) was measured on turkey carcasses at the pectoral muscle 20-30 minutes, 3h, 6h after slaughter. The pH_{24h} was measured at 24 hours, at 4 ± 2 ° C, taken on the right pectoral muscle with a penetrating electrode connected to a portable pH-meter type microcomputer HI 99163 (HANNA instruments).

2.2. Meat color

The color was measured after 24 hours postmortem on a section of the pectoral muscle at 4 ± 2°C. The meat samples were measured for chromaticity using a Minolta Chromameter CR-410 (Minolta). The colorimeter was standardized using a white tile with illuminance D65. The CIELAB color space has been used in the color measurement. Chromaticity coordinates, luminance (L*), the index to red (a *) and yellow index (b *) were measured three repetitions on muscle surface and averaged for statistical analysis (Pietrzak et al., 1997).

2.3. Shear force

Slices of pectoralis *major* were cut rectangular parallelepipeds, around 1*1 cm-thick and 2–3 cm-long, were cut parallel to the muscle fibres. Shear force was measured on meat aged 3 days post-mortem. Raw meat texture was measured in the longitudinal configuration using a TA-XT plus (Texture analyser, Stable Microsystem, UK) with HDP/BSK, BLADE SET GUILLOTINE (Honikel, 1998).

2.4. Drip losses

Losses to flow were evaluated on samples of 100g turkey raw fillets placed in trays on a paper towel. The trays are kept for 3 days at 4 ° C. The weight difference indicates elapsed amount of water during storage. The difference was measured at 3 days. The percentage of losses is determined according to this equation (Honikel, 1998):

Loss percentages (%) = ((Weight before treatment - Weight after treatment) / weight before treatment) x100

2.5. Cooking losses

The cooking losses are determined according to Wood et al. (1981) and Honikel (1998). They are measured on scallops which have approximately the same weight and the same geometric shape. 100g samples were boiled during 15 minutes in a water bath at 80 ° C. The difference in weight indicates the amount of water lost during cooking.

2.6. Statistical analysis

The data in this completely randomized design was subjected to ANOVA with the general linear model procedure of SAS (9.1). The residual mean square error was used as the error term. Means were separated using Duncan test with a significance level of $P < 0.05$ (SAS, 9.1). Because there was no interaction, trials were pooled and analyzed**.**

3. Results and discussion

In this study, postmortem metabolism was controlled by measuring muscle pH. The effects of transport duration on postmortem pH decline are shown in Table 1. The postmortem decline in muscle pH is due to an accumulation of lactic acid as a result of glycolysis (Khan and Nakamura 1970; Lawrie 1998). Lactic acid production is dependent up on glycogen, as it is the substrate in glycolysis (Lawrie 1998). The preslaughter transport time affected significantly the pH at 20 min, 3h, 6h and at 24h ($p<0.001$). Therefore, the Turkeys that were transported for 15 min to 30 min (T15) prior to slaughter had significantly lower muscle pH at 3, 6h and 24h postmortem. Nevertheless, the turkeys were transported for 2h to 2h30 min (T120) had the lowest pH at 20 min and the highest pH muscle at 24h. It is possible that the long term for transportation caused depletion in glycogen content in the muscle and resulted in higher muscle pH at 24 h postmortem. Owens and Sams (2000) suggested that the turkeys that were transported for 3 h prior to slaughter had significantly higher muscle pH at 0, 2, and 24 h postmortem. So, the transportation for 3 h may cause stress to the animal that accelerates metabolism to a point of depletion of muscle glycogen, resulting in high muscle pH (Owens and Sams 2000).

Table 1. Meat quality attributes of pectoralis major HYBRIDE male turkeys transported for three different times of preslaughter transport

	Transported groups			
	T15[1] 15 to 30 min	**T90[1] 1h15 to 1h30 min**	**T120[1] 2h to 2h30 min**	**P**
pH_{20min}	6.19 ± 0.15a	6.13 ± 0.12b	6.07 ± 0.24c	****
pH_{3h}	5.98 ± 0.09b	6.05 ± 0.11a	6 ± 0.13b	***
pH_{6h}	5.90 ± 0.07b	5.95 ± 0.1a	5.92 ± 0.1b	***
pH_{24h}	5.71 ± 0.1b	5.72 ± 0.07b	5.77 ± 0.15a	***
Rate of pH (Unit pH/h)	0.05 ± 0.02a	0.03± 0.01b	0.02 ± 0.01b	****
L	51.64 ± 2.37	51.62 ± 1.75	51.97 ± 1.84	NS
a*	14.13 ± 1.06	14.19 ± 0.64	13.61 ± 1.24	NS
b*	7.47 ±0.46	7.69 ±1	7.47 ±0.25	NS
Drip loss (%)[2]	2.16 ± 0.39a	1.76 ± 0.29b	1.92 ± 0.32ab	*
Cooking loss (%)[2]	7.62 ± 1.04b	7.55 ± 2.41b	11.93 ± 2.75a	****
Water-holding capacity[2] (%)[2]	9.79 ± 1.76b	9.32 ± 2.57b	13.85 ± 2.81a	****
3d-Shear Force (N)[2]	19.5 ± 9.24b	24.96 ± 9.58a	23.16 ± 9.2a	**

[a,b]Means within row with no common superscript differ significantly ($P < 0.05$)
Level of significance of the effects of transport time: ****P<0.0001; ***P<0.001; **P < 0.01; *P < 0.05; NS, P > 0.10
[1]n=100 for each group
[2]the attributes were measured at 3 day post-mortem
L* = lightness; a* = redness; b* = yellowness

Researchers have also evaluated transportation effects on the meat quality of pigs and have found similar results as observed in the present study. Geers et al. (1994) observed that transporting pigs for 2 h decreased muscle glycogen content, suggesting that transportation has a glycogenolytic effect. Gigaud et al. (2006) showed that the ultimate pH increased significantly beyond 2h of transport. McPhee and Trout (1995) and Becker et al. (1989) reported that pigs transported for long periods of time (10 to 11 h) had higher ultimate pH compared with pigs transported for short periods (<0.5h transport).They suggested that transportation imposes acute demands on energy metabolism. Because glycogen is converted to lactic acid during glycolysis, a decreased amount of glycogen will result in less glycolysis and a higher ultimate pH (Lawrie 1998). Previously, researchers have found that transportation stresses animals (poultry and swine), as indicated by increases in plasma corticosterone and cortisol concentrations (Freeman et al. 1984; Kannan et al. 1997; Brown et al. 1998). Several studies have suggested that poultry, when subjected to long-term transport, consistently develop hypoglycemia that may be the result of exhaustion of hepatic glycogen stores (Halliday et al. 1977; Freeman et al. 1984).
Color measure is an important meat quality attribute and is often used as an indicator of PSE and DFD meat. In addition, the luminance L* value is highly correlated with muscle pH and water-holding

capacity (Barbut 1993, 1997). Owens and Sams (2000) reported that lower muscle pH of transported turkeys results in higher L* values. In the current study, the pH at 24h and the rate of pH were affected by transport time. The rate of pH decline decreased significantly with time transport ($p<0.0001$). Furthermore, the rate of pH decline can affect meat color and WHC through protein denaturation (Warris and Brown, 1987). However, luminance, red index and yellow index were not affected by transport time. The long-term of transport increased the pHu and decreased the luminance and yellow index b*(Gigaud et al. 2006). Zhang et al. (2009) suggested that transportation broilers for long duration did not affect L* index neither a*index nor b*index. Moreover, large differences in the rate of pH decline in turkey breast muscle did not induce meat luminosity modifications: meat color alterations cannot be used as an indicator of a high rate of pH decline, concluded Molette et al. (2005).

Color and texture are mainly considered by consumers, whereas water-holding capacity is an issue of concern for the meat processing industry. Water-holding capacity is another important meat quality attribute and can be evaluated by cook loss and drip loss. In this study,water-holding capacity of meat was evaluated using fillets stored for 3 days at 4°C and then cooked. Consequently, we evaluated drip and cook losses. Postmortem metabolism can affect the functionality of meat proteins responsible for water-holding capacity (Swatland 1993). Transporting turkeys for different time, in the current study, affected drip loss ($p <0.05$) or cook loss ($p <0.0001$) of turkey breast (Table 1). Water-holding capacity has been significantly correlated with muscle pH, indicating that lower cook losses are associated with higher muscle pH and better protein functionality (Barbut 1993). Higher muscle pH values are further from the isoelectric point of the contractile proteins; therefore, the proteins are more functional, resulting in lower cook losses (Hedrick et al. 1989; Lawrie 1998). Transportation of animals has previously been shown to increase water-holding capacity in turkeys and in swine (van Hoof 1979; Becker et al. 1989, Mc Phee and Trout, 1995). It is generally held that the water-holding capacity of PSE meat (pork or poultry) is low. This is demonstrated for cook loss in turkey (Froning et al. 1978; McKee and Sams 1998) and chicken (Woelfel et al. 2002), or processing ability (Pietrzak et al. 1997; Rathgeber et al. 1999a;VanLaack et al. 2000). Molette et al. (2005) considered that a higher rate of pH decline induced lower water-holding capacity and a lower processing ability of turkey meat. Because water is mainly fixed in protein in muscle, several authors have suggested that low water-holding capacity in PSE meat should be due to protein alterations induced by the combination of low pH and high temperature. Offer (1991) suggested that, when myosin is placed in conditions similar to those encountered in PSE carcasses, the myosin heads shrink from 19 to 17 nm. This small amount of shrinkage should be sufficient to draw the thin and thick filaments closer together, resulting in a higher quantity of water expelled. Nevertheless, it cannot be excluded that alteration of other proteins occurred and contributed to a more significant water release.The reduced water-holding capacity of the meat is the result of protein damage from the low pH condition of the muscle early after death; such as in this study. A long-term of transport induced a lower pH at 20 min post-mortem. It is thought that this damage is at least partially reversible by adjustment of pH or ionic strength in the meat through the use of salts, phosphates, or other ingredients (Owens et al. 2009). However, there is no strong evidence to show that adjusting the pH or ionic strength alone can reverse the problem (Woelfel and Sams 2001).

Tenderness of meat, in this study, was evaluated using HDP/BSK blade shear force test on raw meat (Table 1). The meat of turkey transported for >1h15 min had a higher shear force value than meat of turkey transported for the short time (T15). The lower tenderness of meat of turkey transported for 2h (T120) indicates that a lower pH at 20 min at higher temperature may alter the quality of meat, as observed in PSE meat. According to Lawrie (1998) and McKee and Sams (1998), the lower tenderness is due to a shortened sarcomere length and a higher moisture loss in rigor development at elevated temperature. Molette et al. (2005) considered that sarcomere lengths were only slightly higher for FG meat than for NG meat. They assume that the resulting toughness appeared to be mainly related to modified moisture loss.

4. Conclusion

The results of the present study suggest that transportation of turkeys for more than 1h30 affected negatively meat quality; it resulted in lower muscle pH at 20 min close the ultimate pH, lower water holding capacity and the lower tenderness. We can conclude that our samples have the same behavior as PSE samples. However, these metabolic changes were not significant enough to be detrimental to meat quality in this study.

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