

## SHELF LIFE AND COLOUR CHARACTERISTICS OF THIGH MUSCLES OF TURKEYS PACKAGED UNDER MODIFIED ATMOSPHERE

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Key words: colour, haem pigments, turkey, modified atmosphere, microflora

The colour of the turkey thigh muscles packaged under modified atmosphere (MA) and stored under refrigeration conditions was investigated. The aim was realized by: determination of total haem pigments (TP) concentration, relative concentration of deoxy- (Mb), oxy- (MbO<sub>2</sub>) and metmyoglobin (MMb), parameters of colour L\*, a\*, b\* and sensory evaluation of the colour. The time of storage was limited by the total count of bacteria. It was established that turkey muscles packed under MA, can be stored for 15 days and in the air for 4 days only. The TP concentration and the three myoglobin forms were at the same level up to 4 days for samples stored under MA and in the air. After that period, they changed significantly. The relative concentration of Mb, MbO<sub>2</sub>, MMb in samples stored under MA and in the air were at the same level over the entire time of storage. The sensory evaluation of surface colour of samples packaged under MA changed significantly on the 8<sup>th</sup> day of storage, and in the control samples on the 4<sup>th</sup> day. Among the colour parameters only the L\* values did not change for 15 days of storage in the samples packaged under MA and in the control samples. The a\* values decreased significantly on the 8<sup>th</sup> day for samples stored under MA, however in the control samples they did not change up to the 4<sup>th</sup> day. The b\* parameter increased significantly on the 4<sup>th</sup> day both for samples stored under MA and in the air.

### INTRODUCTION

Meat quality is determined by a number factors. One of them is colour. It is a very important factor which often determines whether the consumer will purchase the product or not. The colour of meat depends, among others, on such factors as: concentration and chemical state of pigments, and physical structure of meat [Millar, 1996; Renner, 1999]. The main pigment responsible for the characteristic colour of fresh meat is myoglobin. Three myoglobin forms include: bright red oxymyoglobin (MbO<sub>2</sub>), purple red deoxymyoglobin (Mb) and brown metmyoglobin (MMb), dependent on the partial pressure of oxygen in the atmosphere [Pikul *et al.*, 1988; Krala, 2001; Faustman, 2001; Dhanda *et al.*, 2004]. The first two forms easily undergo a change of one into another. The creation of the brown MMb is practically irreversible [Wichlacz & Krzywicki, 1986].

To extend the shelf life of fresh chilled meat and provide its attractive appearance one can use packaging and storage under modified atmosphere (atmosphere with changed proportions of: carbon dioxide, oxygen and nitrogen, and with using package materials with adequate high barrier for the above-mentioned gases) [Fraqueza *et al.*, 2004; Tremonte *et al.*, 2004; Ho *et al.*, 2003].

The objective of the work was to characterise the colour of the turkey thigh muscles packaged under modified atmosphere composed of: 75% CO<sub>2</sub>, 20% N<sub>2</sub>, 5% O<sub>2</sub>, and stored under the refrigeration conditions.

The aim was to be accomplished by: determination of total haem pigments (TP) concentration, relative concentration of Mb, MbO<sub>2</sub> and MMb, parameters of colour L\*, a\*, b\* and sensory assessment of the colour. Microbiological tests included determination of the total number of bacteria, *Pseudomonas* and *Lactobacillus*. The time of storage was limited by the total count of bacteria.

### MATERIALS AND METHODS

The experimental material covered the thigh muscle portions (without skin and bones) cut out 24 h after slaughter from the industrially slaughtered turkeys. The experiments were repeated three times. The 30 muscles were investigated each time. The thigh portions were packed into high barrier bags (PA/ARE/PE – thickness: 60 µm, permeability (cm<sup>3</sup>/m<sup>2</sup>/24 h/bar) of: oxygen – 47, carbon dioxide – 165 and nitrogen – 28) using a Tepro packaging machine type PP5, and were stored under the modified atmosphere (MA) with the following composition: 75% CO<sub>2</sub>, 20% N<sub>2</sub>, 5% O<sub>2</sub>. The samples were stored in a refrigerator at +1°C and were examined 24 h after slaughter and next on 4, 8, 12, and 15 day of storage. The control samples were packed into HDPE bags and stored in the air at the same temperature.

The haem pigments were extracted using the Warris procedure modified by Pikul [Pikul, 1993]. The relative concentrations of: Mb, MbO<sub>2</sub> and MMb were calculated with the equations given by Krzywicki [1982]. The Hewlett Pack-

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TABLE 1. Criteria of a six-point scale of the sensory assessment of turkey thighs colour.

	Points	Colour
Desirable	6	Intense pink-red, even, typical
	5	Pink-red, even
Tolerated	4	Pink-red
	3	In places noticeable changed lighter or darker pink-red
Undesirable	2	Strongly changed: light, cream or very dark, brown
	1	Completely changed, grey, brown, blue

TABLE 2. Development of bacteria in the chill-stored turkey thigh muscles.

Storage	CS	Air	MA			
		24 hours	4 days	8 days	12 days	15 days
Total count of bacteria (cfu/g)	3.5x10 <sup>5</sup>	2.3x10 <sup>3</sup>	3.7x10 <sup>3</sup>	3.9x10 <sup>4</sup>	6.9x10 <sup>4</sup>	1.4x10 <sup>5</sup>
<i>Lactobacillus</i> (cfu/g)	1.1x10 <sup>3</sup>	2.2x10 <sup>2</sup>	5.7x10 <sup>2</sup>	2.6x10 <sup>3</sup>	6.0x10 <sup>4</sup>	1.5x10 <sup>5</sup>
<i>Pseudomonas</i>	-	-	-	-	-	-

The data are average value of 18 tests; CS - control sample (the 4<sup>th</sup> day of storage in the air); - absent

ard's Diode Array UV/VIS spectrophotometer was used for measuring the pigment extract absorbance. Colour of the turkey thigh muscles was measured by the spectrophotometric method in the CIE L\*, a\*, b\* system [Michałowski, 1995], using the chromameter Minolta type CR 310.

The sensory assessment of colour was conducted by a sensory panel (7 persons) who used a six-point scale: 1 point means the lowest, 6 points the highest evaluation (Table 1). This scale was made on the basis of criteria specified by the Polish Norm [PN-ISO 4121:1998].

Microbiological tests included determination of the total number of bacteria and *Lactobacillus* in 1 g of the investigated sample and the presence of *Pseudomonas*. The analyses were made according to respective Polish Norms [PN-A-82055-6:1994; PN-A-82055-17:1997; PN-ISO 13720:1999]. The time of storage was limited by the total count of bacteria.

In the study, use was made of American norms, which give the total number of bacteria in 1 g of chilled meat, at a level of 5 x 10<sup>5</sup> cfu/g [Shapton, 1993], as Polish norms do not describe the permissible value of the total number of bacteria in 1 g of chilled meat.

The data obtained were analysed statistically. The Student's t-test was used to establish differences between average values.

## RESULTS AND DISCUSSION

During cold storage, the total count of bacteria and *Lactobacillus* was observed to increase (Table 2). The examined muscles were characterised by the total count of bacteria at a level of 2.3 x 10<sup>3</sup> cfu/g and *Lactobacillus* - at a level of 2.2 x 10<sup>2</sup> cfu/g 24 h after slaughter. On the 15<sup>th</sup> day of storage under MA, the total count of bacteria accounted for 1.4 x 10<sup>5</sup> cfu/g and that of *Lactobacillus* - for 1.5 x 10<sup>5</sup> cfu/g. In

the case of the control samples, the total count of bacteria was near the permissible value - 3.5 x 10<sup>5</sup> cfu/g, and that of *Lactobacillus* reached 1.1 x 10<sup>3</sup> cfu/g already on the 4<sup>th</sup> day of storage in the air.

On the basis of microbiological tests, it was established that turkey muscles packed under MA can be stored for 15 days and those packed in the air for as little as 4 days. The total count of bacteria was higher than 5 x 10<sup>5</sup> cfu/g after these times, but sensory symptoms of meat deterioration stored under modified atmosphere and in the air were not observed. *Pseudomonas*, which are responsible for deterioration of the chilled meat, were not detected over the entire time of storage (Table 2).

The TP concentration and the three myoglobin forms were at the same level up to 4 days for meat stored under MA and in the air (Table 3). After that period, they changed significantly. The TP concentration after 24 h was at a level of 2.46 mg/g, however after 15 days of storage it dropped to 1.46 mg/g. For the myoglobin forms the changes were respectively: Mb - from 0.81 to 0.44; MbO<sub>2</sub> - from 1.13 to 0.73; MMb - from 0.52 to 0.29 mg/g. The relative concentration of Mb, MbO<sub>2</sub>, MMb samples stored under MAP and in the air were at the same level over the entire time of storage. The relative concentration of Mb accounted for 30-33%, that of MbO<sub>2</sub> for 46-50% and that of MMb for 18-21% in meat stored under modified atmosphere and respectively for 33%, 45% and 22% in control samples stored for four days in the air (Table 3). Skrabka-Błotnicka et al. [2002] observed a decrease in the concentration of TP (as well as a decrease in the concentration of the Mb, MbO<sub>2</sub>, MMb), with unchanged relative concentration of three myoglobin forms in the vacuum-packed ducks' muscles.

The fact of TP concentration decrease (with unchanged relative concentration of myoglobin forms) is likely to indicate that the Mb, MbO<sub>2</sub> and MMb were equally utilized by

TABLE 3. Haem pigment concentration in the turkey thigh muscles packaged under modified atmosphere (MA) and in the air.

Storage time	TP		Mb			MbO <sub>2</sub>			MMb		
	$\bar{X}$	SD	RC	$\bar{X}$	SD	RC	$\bar{X}$	SD	RC	$\bar{X}$	SD
CS	2.27 <sup>a</sup>	0.25	0.33	0.75 <sup>a</sup>	0.02	0.45	1.02 <sup>a</sup>	0.03	0.22	0.50 <sup>a</sup>	0.03
air											
24 hours	2.46 <sup>a</sup>	0.71	0.33	0.81 <sup>a</sup>	0.03	0.46	1.13 <sup>a</sup>	0.04	0.21	0.52 <sup>a</sup>	0.03
MA											
4 days	2.36 <sup>a</sup>	0.37	0.32	0.76 <sup>a</sup>	0.02	0.48	1.13 <sup>a</sup>	0.06	0.20	0.47 <sup>a</sup>	0.04
8 days	1.90 <sup>b</sup>	0.28	0.32	0.61 <sup>b</sup>	0.03	0.50	0.95 <sup>b</sup>	0.13	0.18	0.34 <sup>b</sup>	0.10
12 days	1.71 <sup>b</sup>	0.08	0.30	0.51 <sup>b</sup>	0.02	0.49	0.84 <sup>b</sup>	0.07	0.21	0.36 <sup>b</sup>	0.06
15 days	1.46 <sup>c</sup>	0.11	0.30	0.44 <sup>c</sup>	0.02	0.50	0.73 <sup>c</sup>	0.08	0.20	0.29 <sup>c</sup>	0.07

CS – control sample (the 4<sup>th</sup> day of storage in the air);  $\bar{X}$  - The average values of 18 tests (mg/1g of tissue); SD – standard deviation; RC – relative concentration; a, b, c – values with different letters at the same column differ at  $p < 0.05$

TABLE 4. Evaluation of the turkey thigh muscles colour.

Storage	CS		Air		MA							
			24 hours		4 days		8 days		12 days		15 days	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
L*	45.61 <sup>a</sup>	1.71	45.25 <sup>a</sup>	1.45	44.63 <sup>a</sup>	1.88	44.73 <sup>a</sup>	1.59	45.23 <sup>a</sup>	1.33	45.48 <sup>a</sup>	1.82
a*	16.67 <sup>a</sup>	0.65	16.99 <sup>a</sup>	0.88	16.32 <sup>a</sup>	0.60	14.96 <sup>b</sup>	1.01	14.32 <sup>b</sup>	0.49	13.98 <sup>b</sup>	0.76
b*	4.39 <sup>b</sup>	0.98	3.29 <sup>a</sup>	0.71	4.96 <sup>b</sup>	0.89	5.38 <sup>b</sup>	0.78	5.69 <sup>b</sup>	0.32	5.37 <sup>b</sup>	1.10
SE (points)	4.39 <sup>b</sup>	0.15	5.47 <sup>a</sup>	0.19	5.26 <sup>a</sup>	0.09	4.70 <sup>b</sup>	0.33	4.53 <sup>b</sup>	0.27	4.13 <sup>c</sup>	0.31

$\bar{X}$  – the average values of 18 tests; SE – sensory evaluation of colour; CS – control sample (the 4<sup>th</sup> day of storage in the air); SD – standard deviation; a, b, c – values with different letters at the same level differ at  $p < 0.05$

microorganisms as a source of iron; and/either that the bacterial enzymes or metabolites reacted with those forms of myoglobin, creating compounds which cannot be estimated by common methods used for haem pigments determination. Kędzia [1982] and Krala [1995] informed about unfavourable changes of the surface colour of meat as a result of bacterial enzymes activity. Robach and Costilow [1961] observed that meat colour changes were caused by increasing counts of aerobic bacteria which used oxygen. Renner [1999] reported that according to Faustmann and Cassen [1990], 10<sup>8</sup> cfu of psychrotrophic bacteria/g are needed to start the oxidation-reduction mechanisms.

The colour of turkey thigh muscles was defined by the sensory panel as intensive pink-red (Table 1). The sensory evaluation of the surface colour of samples packaged under MA changed significantly on the 8<sup>th</sup> day of storage, and for the control samples - on the 4<sup>th</sup> day, although at the end of storage they were recognized as desirable. Among the colour parameters only the L\* values did not change for 15 days of storage both in the samples packaged under MA and in the control ones. The a\* values decreased significantly on the 8<sup>th</sup> day for samples stored under MA, and for the control samples they did not change up to the 4<sup>th</sup> day. The b\* parameter increased significantly on the 4<sup>th</sup> day for samples stored under MA and in the air (Table 4). The sensory evaluation of the muscle surface colour was reflected in the instrumental measurements. A significant increase of b\* parameter – from the 4<sup>th</sup> day of storage under MA as well as a decrease of a\* parameter on

the 8<sup>th</sup> day caused a significant decrease in the sensory evaluation scores of the investigated muscles' colour from 5.47 to 4.70 on the 8<sup>th</sup> day of storage. The colour of control samples received the similar sensory scores (no significant differences) to the samples stored in MA for 12 days (Table 4).

It may be supposed that the obtained data (haem pigments content, Mb, MbO<sub>2</sub>, MMb, colour parameters and sensory assessment) were affected to a great extent by the modified atmosphere composition, high barrier film used to packaging as well as temperature of storage of the investigated samples.

## CONCLUSION

Using the high barrier PA/ARE/PE bags and packaging under the MA consisting of 75% CO<sub>2</sub>, 20% N<sub>2</sub>, 5% O<sub>2</sub> may prolong the shelf life of turkey thigh muscles up to 15 days, which is about 3-4 times longer as compared to the muscles stored in the air, and contributes to preserving the desirable colour of stored meat.

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## TRWAŁOŚĆ PRZECHOWALNICZA ORAZ CHARAKTERYSTYKA BARWY MIĘŚNI UDOWYCH INDYKÓW PAKOWANYCH W MODYFIKOWANEJ ATMOSFERZE

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Badano barwę mięśni udowych indyków pakowanych w modyfikowanej atmosferze (MA) o składzie: 75% CO<sub>2</sub>, 20% N<sub>2</sub>, 5% O<sub>2</sub> i przechowywanych w warunkach chłodniczych. Cel pracy zrealizowano przeprowadzając: oznaczenie ogólnej zawartości barwników hemowych (OZB), względnej zawartości: deoxy- (Mb), oxy- (MbO<sub>2</sub>) i metmyoglobiny (MMb), parametrów barwy: L\*, a\*, b\* oraz ocenę sensoryczną barwy. Równolegle wykonywano badania mikrobiologiczne w oparciu, o które przyjęto, że 15 dzień przechowywania mięśni pakowanych w MA oraz 4 dzień prób przechowywanych w powietrzu był ostatnim dniem przydatności tych mięśni do spożycia. W prowadzonych badaniach zaobserwowano, że OZB oraz trzy formy mioglobiny nie zmieniły się do 4 dnia przechowywania zarówno w mięśniach pakowanych i nie pakowanych w MA. Po tym czasie uległy istotnym zmianom. W całym okresie przechowywania prób w modyfikowanej atmosferze i powietrzu, nie zmienił się względny udział poszczególnych form mioglobiny. Spośród badanych parametrów barwy w całym okresie przechowywania chłodniczego mięśni pakowanych w MA jak i prób kontrolnych, nie zaobserwowano zmian parametru L\*. Wartość parametru a\* zmniejszyła się istotnie w 8 dniu dla mięśni pakowanych w MA, natomiast dla prób kontrolnych nie zmieniła się do 4 dnia przechowywania. Wartość parametru b\* wzrosła istotnie w 4 dniu przechowywania zarówno dla prób pakowanych w MA jak i prób kontrolnych. Ocena sensoryczna barwy powierzchni mięśni pakowanych w MA zmieniła się istotnie w 8 dniu przechowywania, a w przypadku prób kontrolnych w 4 przechowywania.