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Influence of combined, continuous chilling on physical and chemical properties of white and red chicken muscles

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ABSTRACT

Research on the influence of combined, continuous chilling on the quality of meat was carried out on young growing broilers of the Hybro line (Euribid, B.V. Boxmeer, Holland). The broilers were 43 to 48 days old with weights ranging from 1465 to 1762 g. The experiments were carried out on 140 samples, on m. iliotibialis lateralis (red muscle) and mm. pectorales superficialis (white muscle). Observed physical properties included temperature measurements, water holding capacity, pH and weight loss of the samples. Water contents in the skin and in the muscles, protein, fat and ash contents were also measured. This research showed that combined, continuous chilling resulted in a temperature decrease of the m. iliotibialis lateralis to 7.64 ^{0}C and of the mm. pectorales superficialis to 10.83 ^{0}C. Water activity also decreased for both muscles. White muscle had a higher water holding capacity (7.19 cm^2) than red muscle (9.40 cm^2), and after chilling both muscles showed a reduction in this parameter. Water content in skin and in muscles increased in chilled samples. The results showed a weight gain of 0.92 ± 0.5 % due to absorbed water during the water chilling phase. This method of chilling showed no significant influence on other physical and chemical properties of poultry meat.

Key words: chicken, muscles, chilling, physical changes, chemical changes

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Introduction

Combined, continuous chilling consists of showering and draining and two phases of air chilling during a 55-minute period.

Poultry meat is widely accepted as a good source of high-quality protein. Breast muscle (mm. pectorales superficialis, white muscle) is the most important muscle in the chicken economically, and the m. iliotibialis (red muscle) of the thigh also contributes substantially to the overall economy. As the breast muscle is characterised as exclusively consisting of white glycolytic type IIB fibres, and m. iliotibialis of the thigh contains approximately 30% oxidative-glycolytic fibres, they differ in some important physical properties. Water holding capacity and pH are different in these two muscles, revealing their different structure (HENCKEL et al., 2003). In poultry meat, several methods have been applied to determine water holding capacity, such as the bag drip method (WOELFEL et al., 2002) or the filter paper compression method (URBIN et al., 1962). Determination of water holding capacity is generally subjected to very large variations, which is either due to methodological error or to the existence of large intra-muscular variations. Of the traditional methods, the compression method appears to be the most reliable (HENCKEL et al., 2003).

The carcass chilling process is considered to be a critical step in poultry processing. Reduction of temperature inhibits or even halts the growth of bacteria and has an influence on the physical properties of carcasses (GUMHALTER KAROLYI et al., 2003). Water activity, which is defined by the chemical potential of water, measures the availability of water for microbial growth, and is influenced by temperature. Water holding capacity and water activity has an influence on meat quality and are further influenced by chilling.

There are two main methods commonly used for primary chilling of poultry carcasses: water immersion chilling and dry air chilling (ALLEN et al., 2000). The high risk of cross-contamination in water chilling is well documented and cannot be prevented (BLANK and POWELL, 1995; JAMES et al., 1992). Better microbiological quality of carcasses is obtained by counter flow water chilling compared to parallel flow (PETRAK et al., 1999). With air chilling, the problems associated with water chilling are avoided, but survival of bacteria is still possible. In this method of chilling the microbiological status of carcasses depends to a great deal on the hygiene status of earlier stages in the processing line (FRIES, 2002). By measuring water activity of the food, it is possible to predict shelf-life. From a technological point of view it is important to minimize evaporation of water during air chilling, as well as inadequate absorption of water during the water immersion chilling. During water immersion chilling, absorption of water can be 12%, with an average value of 8%, and during the air chilling weight loss is 5-8% (LILLARD, 1982). Therefore, for achieving adequate quality of poultry meat, it is crucial to choose an optimal method of chilling (ABURUWAIDA et al., 1994).

The aim of this study was to investigate the influence of the combined continuous method of chilling on physical and chemical properties of m. iliotibialis (red muscle) and mm. pectorales superficialis (white muscle).

Materials and methods

The broilers were aged 43 to 48 days, with weights ranging from 1465 to 1762 g. During the first 22 days they were fed a feed mixture containing 22% crude protein, and after that period a feed mixture containing 18% crude protein. The experiments were carried out on 140 samples in a poultry processing plant at Belje, Croatia.

After preliminary slaughtering processes (dressing and evisceration operations) the combined continuous chilling method was carried out over a 55-minute period. After showering and draining (first phase of the chilling), carcasses were chilled in two chambers (first chamber temperature was 1.5 ºC, relative humidity 50% and air velocity 2.5 m/sec; second chamber temperature was -8 ºC, relative humidity 95% and air velocity 3.5 m/sec).

The physical (temperature, pH, water holding capacity and water activity) and chemical properties (water content in skin and in muscles, protein, fat and ash contents) of the m. iliotibialis lateralis (red muscle) and mm. pectorales superficialis (white muscle) were determined on hot and chilled samples, and statistical analysis (analysis of variance) was carried out.

Poultry weight was measured by Mettler weighing-machine, temperature by digital thermometer Dalmacija, pH value by electrode HEC0101 and water activity by measuring instrument Luft Gmb H, Stuttgart. Water holding capacity was determined by the compression method (GRAU and HAMM, 1952), where the pressed-out water was determined using planimeter No 317E Haff Gmb 8962 Pfronten-1, Germany. Chemical analysis of water, protein, fat and ash contents was carried out following analytical procedures (NAUMANN and BASSLER, 1976).

Results

Results of chemical analysis showed the expected relationships in chemical parameters between m. iliotibialis lateralis and mm. pectorales superficialis of broilers of approximately seven weeks of age (Tables 1 and 2). Red muscle had increased water and fat content compared to white muscle, whereas white muscle had increased protein and ash content compared to red muscle. After the chilling phase, contents of chemical parameters were unchanged, except for water content in skin as well as in muscles, which was increased.

Table 1. Analysis of chemical parameters of hot and chilled m. iliotibalis lateralis and mm. pectorales superficialis

Chemical parameters (%)	Mean values and standard deviation			
	m. iliotibalis lateralis		mm. pectorales superficialis	
	hot	chilled	hot	chilled
Water (muscles)	76.86 ± 0.66	77.43 ± 0.6	74.34 ± 0.46	75.14 ± 0.48
Water (skin)	52.56 ± 3.74	55.09 ± 3.02	52.35 ± 4.76	57.13 ± 4.36
Fat (muscles)	2.59 ± 0.42	2.21 ± 0.80	1.07 ± 0.31	1.1 ± 0.48
Protein (muscles)	19.46 ± 0.44	19.34 ± 0.46	23.45 ± 0.41	22.62 ± 0.46
Ash (muscles)	1.03 ± 0.11	0.95 ± 0.25	1.08 ± 0.20	1.08 ± 0.21

Table 2. Results of statistical analysis for chemical parameters (analysis of variance) of hot and chilled m. iliotibalis lateralis and mm. pectorales superficialis

Analysis of variance		
Chemical parameter	Differences between muscles	Differences between hot and chilled samples
Water (muscles)	f (1/76) = 371.996 P<0.01 s	f (1/76) = 31.301 P<0.001 s
Water (skin)	f (1/76) = 1.040 P<0.311 ns	f (1/76) = 16.4 P<0.001 s
Fat (muscles)	f (1/76) = 120.048 P<0.001 s	f (1/76) = 2.057 P=0.156 ns
Protein (muscles)	f (1/76) = 1350 P = 0.001 s	f (1/76) = 23.131 P<0.001 ns
Ash (muscles)	f = 3.979 P<0.05 s	f = 0.744 P = 0.391 ns

s = significant; ns = not significant

Table 3. Analysis of physical parameters of hot and chilled m. iliotibalis lateralis and mm. pectorales superficialis

Physical parameter	Mean values and standard deviation			
	m. iliotibalis lateralis		mm. pectorales. superficialis	
	hot	chilled	hot	chilled
Temperature (°C)	33.02 ± 1.84	7.64 ± 1.07	36.49 ± 1.55	10.83 ± 1.14
pH	6.42 ± 0.12	6.41 ±0.12	6.21 ± 0.27	6.23 ± 0.20
Water activity	0.991 ± 0.004	0.989 ± 0.003	0.991 ± 0.004	0.990 ± 0.002
Water holding capacity (cm^2)	9.40 ± 2.31	11.46 ± 1.53	7.19 ± 2.16	11.46 ± 1.50

Table 3 presents average values of the physical parameters of the samples before and after chilling. As can be observed, the temperature of carcasses decreased to 7.64 °C for red muscle, and to 10.83 °C for white muscle. Measurements of pH-value and water holding capacity showed different values when red and white muscles were compared. pH value was increased and water holding capacity was decreased in red muscle, compared to white muscle. The only physical property that was not different between the two examined muscles was water activity (0.991), but this parameter significantly decreased after chilling ($p<0.05$). Our results showed no difference in pH value after chilling, but chilling caused a decrease in water holding capacity for both muscles (Table 4). The results showed a gain in weight of 0.92 ± 0.5 % (Table 5).

Table 4. Results of statistical analysis for physical parameters (analysis of variance) of hot and chilled m. iliotibalis lateralis and mm. pectorales superficialis

Analysis of variance		
Physical parameter	Differences between muscles	Differences between hot and chilled samples
Temperature (°C)	F (1/76) = 107.34 P<0.001 s	F (1/76) = 6322.89 P<0.001 s
pH	F (1/76) = 22.09 P<0.001 s	F (1/76) = 0.0 P = 0.991 ns
Water activity	F (1/76) = 0.092 P = 0763 ns	F (1/76) = 4.498 P<0.05 s
Water holding capacity (cm^2)	F (1/76) = 29.33 P<0.001 s	F (1/76) = 20.23 P<0.001 s

s = significant; ns = not significant

Table 5. Weight loss of carcasses after chilling process

Carcasses weight - hot samples (g)	1163 ± 194.9
Carcasses weight - chilled samples (g)	1174.6 ± 131.17
Weight gain (g)	10.88 ± 7.9
Weight gain (%)	0.92 ± 0.5

Discussion

The fact that poultry meat is considered to be a good source of lean meat has resulted in a significant increase in poultry meat consumption around the world. When skin is present, the fat level is higher because skin includes subcutaneous fat. Relationships in chemical contents between red and white muscle are compatible with the study by BARBUT (2002). Water content in the skin, as well as in the muscles, was increased owing to absorption of water during the showering phase of chilling.

The combined method of chilling is a hybrid between water and air chilling. In air chilling, the critical parameter is evaporation, whereas in water chilling, it is absorption of water. When combined, these two effects should result in unchangeable weights of the

carcasses. Results obtained in this study showed a weight gain of 0.92%, as a result of absorption of water during the of water chilling phase (showering phase).

Temperature of carcasses was decreased to 7.64 °C for red muscle, and to 10.83 °C for white muscle. The chilling step should allow the removal of body heat from around 39 ºC to about 5 ºC within a few hours. In the combined method of chilling, after spray and air chilling carcasses are chilled in the third chamber until they reach a temperature of 4 ºC. The chilling process (showering, draining and air chilling) lasts for 55 minutes. A potential problem associated with chilling the meat too rapidly is cold-shortening, resulting in exudation (drip loss) and toughening. In this case, the time interval between slaughter and chilling is usually sufficient to prevent the toughening associated with cold-shortening.

Temperature reduction resulted in decreased water activity for both examined muscles. Since meat is categorized as a food with high moisture content, this behaviour was anticipated (LABUZA, 1984). Water activity decreased after chilling to 0.989 (red muscle) and to 0.990 (white muscle), which is in accordance with other researches (WIRTH et al., 1976).

Determining water holding capacity is important for fresh meat cuts sold directly to the consumer, and for processed products. Higher water holding capacity was noted with mm. pectorales superficialis, which is not supported by HENCKEL et al. (2003). The amount of water and degree of holding are affected by factors such as pH, protein type and concentration, number of exposed charged groups, and temperature. The effect of pH is one of the most important factors that can be controlled by the processor. The pH decrease results in an overall reduction of reactive groups on the protein molecules. These reactive groups are those available for water holding, so the shift in pH causes a reduction in water holding capacity. Some loss in water holding capacity is an inevitable consequence of the death of the animal, since pH value reduces in the post-mortem period is a result of lactic acid accumulation (SKRABKA-BLOTNICKA et al., 2003). Our results showed no difference in pH value after chilling, but chilling caused decrease in water holding capacity for both muscles. In this research, temperature decrease was the main factor that influenced the reduction in water holding capacity. The pH values obtained in this study were slightly increased compared to values in literature (ŽIVKOVIĆ, 1986), but relationships between red and white muscles were as expected (SKRABKA-BLOTNICKA et al., 2003).

Conclusion

Combined, continuous chilling caused a reduction in water holding capacity of m. iliotibialis lateralis and mm. pectorales superficialis. Water content in skin and in muscles was increased owing to absorption of water during the showering phase of chilling. Examined muscles showed different pH values and water holding capacities, as well as chemical contents (water, protein, fat and ash).

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SAŽETAK

Istražen je utjecaj kombiniranog, kontinuiranog hlađenja na kakvoću mesa utovljenih pilića linije Hybro (Euribid, B.V. Boxmeer, Nizozemska). Pilići su bili zaklani u dobi od 43 do 48 dana, tjelesne mase 1465-1762 grama. Istraživanje je bilo provedeno na 140 uzoraka, crvenih (m. iliotibialis lateralis) i bijelih (mm. pectorales superficialis) mišića. Istraženi fizikalni pokazatelji obuhvatili su izmjere temperature, sposobnost vezanja vode, pH vrijednost i masu uzoraka. Također, kemijski je analiziran udjel vode u koži i mišićju te udjel bjelančevina, masti i pepela. Rezultati istraživanja pokazali su sniženje temperature m. iliotibialis lateralis (mišić batka) na 7,64 °C, a temperature mm. pectorales superficialis (prsni mišići) na 10,82 °C. Prsni mišići imaju veću sposobnost vezanja vode (7,19 cm^2) u usporedbi s mišićima batka (9,40 cm^2). Nakon provedenog kombiniranog, kontinuiranog hlađenja, obje skupine istraženih mišića očitovale su smanjenu sposobnost vezanja vode. Udjel vode u koži i mišićima se povećao pri hlađenju uzoraka. Rezultati su pokazali porast mase ohlađenih trupova za 0,92 ± 0,5%. Aktivnost vode za obje vrste istraženih mišića značajno se smanjila nakon hlađenja. Opisani način hlađenja nije utjecao na ostala fizikalna i kemijska svojstva pretraženih mišića pilića.

Ključne riječi: pilići, mišići, hlađenje, fizikalne i kemijske promjene