

THE EFFECT OF PACKAGING METHOD AND COLD STORAGE TIME UNDER CONTROLLED ATMOSPHERE CONDITIONS ON QUALITY OF TURKEY BREAST MUSCLE

Jacek Kondratowicz, Żaneta Kułdo, Iwona Chwastowska-Siwiecka,
Ewa Burczyk, Joanna Piekarska

Department of Commodity Science and Animal Raw Material Processing,
University of Warmia and Mazury in Olsztyn, Oczapowskiego 5, 10-957 Olsztyn, Poland

Abstract

The aim of this study was to determine the physicochemical properties and the degree of microbial contamination of turkey breast muscles stored in controlled atmosphere (95% nitrogen, 5% oxygen) at a temperature of 2°C for 5 to 20 days. Meat samples were packaged in PA/PE bags (Nordfilm–Nordform) or left unpackaged. Prolonged cold storage resulted in a gradual increase in the pH of muscles, and their colour became darker. These undesirable qualitative changes proceeded at a slower rate in packaged meat, compared with unpackaged samples. A similar trend was noted with respect to the hydrolytic status of intramuscular lipids, estimated based on acid value. The microbial quality of meat was evaluated based on total microbial counts per g. The level of microbial contamination remained within acceptable limits in packaged breast muscle samples stored in controlled atmosphere for 20 days and in unpackaged samples stored for 10 days.

Key words: turkey breast muscles, controlled atmosphere, packaging method, quality, shelf-life

Fresh poultry meat is offered to consumers in the form of whole carcasses, cuts and muscle fillets which retain their taste and flavour after thermal treatment (Kijowski et al., 2001). Chilled meat, compared with deep-frozen meat, is characterized by better sensory and technological properties and therefore it is preferred by consumers (Kondratowicz and Kawalko, 2003).

Numerous studies have been conducted (Krala, 1999; Pfeiffer and Menner, 1999; Skandamis and Nychas, 2002) to investigate the effect of modified atmosphere packaging and vacuum packaging on the microbial quality and shelf-life of cold-stored poultry meat, whereas there is a scarcity of information regarding the quality of poultry meat stored under controlled atmosphere conditions. Meat can be stored in controlled atmosphere in chilling chambers. The main advantage of this method, in comparison with modified atmosphere packaging, is the possibility to control the

composition of gaseous mixtures applied during cold storage (Eilert, 2005). Controlled atmosphere storage contributes to the microbiological safety and extended durability of meat. This technique is also cost-effective, as the gaseous mixture can be used as a chilling medium (Belcher, 2006).

The aim of this study was to determine the physicochemical properties and the degree of microbial contamination of turkey breast muscles stored in controlled atmosphere (95% nitrogen, 5% oxygen) at a temperature of 2°C for 5 to 20 days. Meat samples were packaged in PA/PE bags (Nordfilm–Nordform) or left unpackaged.

Material and methods

The experimental materials comprised heavy-type turkey-hens with live body weight of approximately 10 kg, reared to 16 weeks of age in a private farm. Slaughter and carcass processing were carried out by an industrial method, in line with the relevant sanitary regulations and technological standards (PN-A-86530, 1998). Carcasses were chilled to around 2°C by a two-stage method in a chilling tunnel, for 12 hours.

Breast muscle (*musculus pectoralis*) samples of normal quality were analysed. The criterion of quality assessment was the value of pH₁ determined in breast muscles with a Radiometer pH-meter, within 15 to 20 minutes postmortem. Normal-quality muscles were those whose pH₁ ranged from 5.90 to 6.20 (Gardzielewska et al., 2003).

In the experiment turkey breast muscles were cold-stored in controlled atmosphere. A total of 80 breast muscle samples, each weighing about 300 g, were divided into two equal groups: 40 samples were packaged in PA/PE bags (Nordfilm–Nordform) and 40 samples were left unpackaged. Packaging was performed at 4°C, under standard conditions in a poultry plant, in accordance with ISO 9002 and HACCP, using a Multivac packaging machine, model A 300/52. Multilayer Nordfilm–Nordform foil 208 (thickness 80 µm, weight 78 g/m²), with oxygen permeability (0% RH) of 53, nitrogen permeability (0% RH) of 21, and carbon dioxide permeability (0% RH) of 134, was used.

Breast muscle samples were stored in a KA–600 chilling chamber. A mixture of liquefied nitrogen and oxygen was supplied automatically (Air Liquide TS–500). Storage conditions were as follows: temperature – 2°C, gaseous nitrogen concentration – 95%, oxygen concentration – 5%, relative humidity – 40%. Gaseous mixture composition was controlled with a gas meter, accurate to 0.2%. Temperature was measured automatically with a Therm thermometer, and relative humidity with a psychrometer. Samples were stored for 5 to 20 days.

Meat quality assessment

In order to prepare meat for laboratory analyses, the outer adipose and tendinous tissue was removed from the sample surface. Samples were ground in a laboratory mill with a mesh size of 2 mm and the meat mass obtained was thoroughly mixed.

The following quantitative and qualitative analyses of meat were performed after 5, 10, 15 and 20 days of cold storage:

- total weight loss during storage – by weighing samples at the beginning and at the completion of each stage of storage, accurate to 1 g,
- dry matter content – by protein denaturation using 96% ethyl alcohol, followed by drying at 105°C (PN-ISO 1442, 2000),
- meat acidity – based on the pH of water homogenates (at a meat to distilled water ratio of 1:1), using a GK 2311 C electrode and a Radiometer pH-meter (PN-ISO 2917/Ap1, 2002),
- colour brightness – based on the percentage of light reflection against the surface of ground meat samples, using a Specol spectrometer and an R45/O remission attachment, at a wavelength of 560 nm (with a magnesium oxide plate as a reference standard of whiteness),
- water-holding capacity – by the Grau-Hamm method (Oeckel et al., 1999),
- acid value (PN-EN ISO-660, 2009),
- total microbial counts (PN-EN ISO 4833, 2004) – in a standard culture medium (Merck); the results are given as common logarithms of colony-forming units per g of meat.

The results were validated statistically. Arithmetic means (\bar{x}) and standard deviations (s) were determined, and the significance of differences between mean values in experimental groups was estimated by Duncan's test, using Statistica 7.0 software.

Results

Table 1 presents the total weight loss of turkey breast muscles stored in controlled atmosphere, as dependent on packaging method and cold storage time. Weight loss increased with time, and after 20 days it was significantly higher in unpackaged muscles (2.77%) than in samples packaged in PA/PE bags (1.76%). In unpackaged samples, weight loss was due to water evaporation and natural drip during cold storage. In packaged samples, weight loss could result from a pressure difference between the outside and inside of packages, leading to forced drip. Foil used in the study provided an effective physical barrier between the product and the environment, thus limiting weight loss due to evaporation (Kijowski et al., 2001; Krala, 1999).

The dry matter content of breast muscles was affected by storage time (Table 1). Dry matter concentration increased with time, regardless of packaging method. The dry matter content of packaged meat samples stored for 5 to 20 days increased from 25.02% to 25.89%. In unpackaged samples dry matter levels increased from 25.55% after 5 days of storage to 26.24% after 20 days. The increase in relative dry matter content resulted, most probably, from drip loss and surface drying of cold-stored meat (Kondratowicz and Kawalko, 2003).

Hydrolytic changes in intramuscular lipids were studied in view of acid value (Table 1). The values of pH₁, measured within 15 to 20 minutes postmortem, were

indicative of good quality of breast muscles. The above values were comparable in both groups, ranging from 6.00 to 6.08, and they remained within the reference standards for normal-quality poultry meat (Gardzielewska et al., 2003). The acidity of breast muscles, measured at the beginning of storage, was similar in both groups and indicated a normal rate of postmortem glycogenolysis. The final acidity (pH_u) of packaged muscles increased slightly (by 0.1 unit) in samples stored for 20 days, in comparison with those stored for 5 days. A higher increase in pH_u was noted in unpackaged breast muscles. Samples stored for 20 days were characterized by the lowest acidity (the highest pH) at 5.76. After 20 days of storage, packaged samples were marked by a significantly lower pH than unpackaged samples.

The colour brightness of breast muscles (Table 1) was significantly affected by packaging method and cold storage time. The colour of packaged samples stored for 5 to 20 days became darker (the percentage of light reflection was 37.00 and 28.90 after 5 and 20 days, respectively). The colour of unpackaged samples stored for 5 to 20 days also became darker (the percentage of light reflection was 34.80 and 29.80, respectively). The most pronounced changes were observed after 15 and 20 days of cold storage.

Water holding capacity, i.e. the ability of meat to retain moisture, is a key quality attribute and an indicator of the processing suitability of meat. As shown in Table 1, the water holding capacity of breast muscles increased with the time of cold storage, regardless of packaging method. In the present experiment, cold-stored breast muscles lost more water due to evaporation and natural drip, which resulted in an apparent increase in their water holding capacity determined by the Grau-Hamm method.

The hydrolytic breakdown of lipids reduces the shelf life of meat products. In our study the rate of changes in intramuscular fat was estimated based on acid value (Table 1). The acid value of packaged muscles stored in controlled atmosphere increased significantly from 6.69 mg 0.1 KOH/1 g after 5 days to 10.29 mg 0.1 KOH/1 g after 20 days. The rate of hydrolysis was insignificantly faster in unpackaged muscles in which acid value reached 11.06 mg 0.1 KOH/1 g after 20 days. According to Krala (1999), the secondary products of lipid hydrolysis may lead to rancidity and cause changes in the colour of muscle tissue during the reaction of aldehydes with proteins, free amino acids and other meat components.

The total count of aerobic bacteria per g of muscle tissue is a good indicator of microbiological safety. The analysed muscles differed significantly with respect to total microbial counts, depending on packaging method and storage time (Table 2). During 20 days of cold storage, the rate of microbial growth was slower in packaged samples, compared with unpackaged samples. Over this period the total microbial counts in packaged muscles did not exceed the threshold limit value set in PN-A-86920 (1998). In unpackaged samples the level of microbial contamination exceeded the above value on day 15 of storage, which suggests that the process of microbial spoilage had already begun. The results of microbiological examinations show that the maximum storage life under controlled atmosphere conditions is 20 days for packaged turkey breast muscles and 10 days for unpackaged muscles. The above indicates that controlled atmosphere storage (95% N_2 and 5% O_2) contributes to extended shelf life of turkey meat.

Table 1. Weight loss, physicochemical properties and acid value of turkey breast muscles depending on packaging method and cold storage time (n=10)

Item	Statistical measures	Packaging method											
		packaged samples					unpackaged samples						
		5	10	15	20	5	10	15	20				
Weight losses during storage (%)	mean	1.51 a	1.77 c	1.75 c	1.76 c	1.49 a	1.62 b	2.23 d	2.77 e				
	SD	0.56	0.70	0.72	0.62	0.18	0.15	0.62	0.79				
Dry matter (%)	mean	25.02 a	25.49 b	25.60 b	25.89 b	25.55 b	25.78 b	25.89 b	26.24 c				
	SD	0.63	0.52	0.40	0.70	0.44	0.33	0.42	0.43				
pH _i	mean	6.00	6.01	6.07	6.06	6.03	6.06	6.08	6.03				
	SD	0.08	0.09	0.11	0.09	0.06	0.09	0.08	0.10				
pH (before storage)	mean	5.51	5.54	5.55	5.50	5.52	5.57	5.60	5.54				
	SD	0.12	0.10	0.07	0.07	0.08	0.14	0.14	0.10				
pH _u (after storage)	mean	5.53 a	5.61 b	5.59 b	5.64 b	5.62 b	5.66 b	5.68 b	5.76 c				
	SD	0.11	0.09	0.14	0.09	0.08	0.10	0.11	0.09				
Colour brightness (%)	mean	37.00 a	31.00 b	30.01 b	28.90 b	34.80 c	33.00 c	30.60 b	29.80 b				
	SD	3.53	5.96	2.71	3.48	2.17	2.49	3.60	1.92				
Water holding capacity (cm ²)	mean	5.21 a	4.22 b	4.33 b	4.05 b	5.01 a	5.03 a	3.82 b	3.76 b				
	SD	1.67	0.96	0.88	0.83	0.78	1.01	0.67	0.63				
Acid value (mg 0.1 KOH/1 g)	mean	6.69 a	7.77 a	9.50b	10.29 c	7.92 a	8.86 b	8.46 b	11.06 c				
	SD	2.17	2.20	6.30	4.34	3.20	3.22	3.33	2.73				

ab... Within lines, means followed by different superscript letters differ significantly at P≤0.01.

Table 2. Total microbial counts in turkey breast muscles depending on packaging method and cold storage time (n = 10)

Item	Statistical measures	Packaging method									
		packaged samples					unpacked samples				
		time of storage (days)									
		5	10	15	20	5	10	15	20		
Total microbial counts (log ₁₀ cfu/g)	mean	1.16·10 ⁴ a	4.16·10 ⁴ a	4.69·10 ⁵ a	9.76·10 ⁵ b	2.08·10 ⁵ b	5.68·10 ⁵ b	6.00·10 ⁶ c	1.28·10 ⁸ d		
	SD	7.29·10 ³	3.25·10 ⁴	3.84·10 ⁵	1.31·10 ⁶	5.91·10 ⁴	1.73·10 ⁵	2.83·10 ⁶	5.99·10 ⁷		
	min.	3.75·10 ³	1.75·10 ⁴	1.13·10 ⁵	5.15·10 ⁴	1.25·10 ⁵	3.84·10 ⁵	3.19·10 ⁶	5.01·10 ⁷		
	max.	2.20·10 ⁴	8.65·10 ⁴	1.10·10 ⁶	2.81·10 ⁶	2.85·10 ⁵	5.01·10 ⁵	7.75·10 ⁶	2.10·10 ⁸		

ab... Within lines, means followed by different superscript letters differ significantly at P ≤ 0.01.

Discussion

There is a scarcity of information regarding the use of controlled atmosphere (95% N₂ and 5% O₂) in cold storage of turkey meat. As demonstrated by Krala (1999), nitrogen delays the onset or slows the development of rancidity due to oxidation, and it inhibits the growth of aerobic microorganisms. Oxygen, as a component of controlled atmosphere, prevents the excessive growth of lactic acid bacteria and limits the growth of anaerobic pathogenic bacteria. According to the cited author, a residual oxygen content in the protective gas mixture is essential in view of consumer health, since it supports the growth of putrefactive bacteria. Those bacteria are responsible for the development of an unpleasant odour that accompanies meat spoilage. Their presence is also indicative of undesirable organoleptic changes in the stored product.

Bacteria of the genus *Pseudomonas* are responsible for the spoilage of chilled meat stored under aerobic conditions. Those microbes speed up protein proteolysis as well as the processes of fat oxidation and hydrolysis. *Pseudomonas* bacteria secrete enzymes which convert complex protein structures and fats into simpler, readily available compounds. The growth of *Pseudomonas* decreases the concentrations of hydrogen ions in muscle tissue, increases the levels of free fatty acids and reduces the amount of oxymyoglobin on the meat surface from 100 to 0% (Kreyenschmidt et al., 2002). The counts of the above bacteria in excess of 5×10^6 cfu/g muscle tissue contribute to the formation of putrid odour, indicating meat spoilage. An increase in the population size of *Pseudomonas* to 5×10^8 cfu/g results in slime development (Blakistone, 1998).

The results of poultry meat storage under controlled atmosphere conditions are significantly affected by storage temperature. Even small temperature fluctuations, in the $\pm 1^\circ\text{C}$ range, during chilled storage cause a substantial increase in bacterial counts and shorten the shelf life of meat by several days. According to the relevant standards (PN-A-86920, 1998), the good keeping quality of chilled turkey cuts stored at ambient temperature of 0 to 2°C can be maintained for approximately 5 days, which was confirmed by the present study. The method of controlled atmosphere storage applied in our study contributed to extending the keeping quality of chilled turkey meat.

In conclusion, the increase in the weight loss of turkey breast muscles was proportional to cold storage time, and it was higher in unpackaged samples than in packaged meat. Prolonged cold storage resulted in a gradual increase in the pH of muscles, and their colour became darker. These undesirable qualitative changes proceeded at a slower rate in packaged meat, compared with unpackaged samples. A similar trend was noted with respect to the hydrolytic status of intramuscular lipids, estimated based on acid value. An evaluation of the microbial quality of meat, based on total microbial counts per g, showed that the level of microbial contamination remained within acceptable limits in packaged breast muscle samples stored in controlled atmosphere for 20 days and in unpackaged samples stored for 10 days.

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JACEK KONDRATOWICZ, ŻANETA KUŁDO, IWONA CHWASTOWSKA-SIWIECKA, EWA BURCZYK, JOANNA PIEKARSKA

Zmiany jakości mięśni piersiowych indyczek przechowywanych w kontrolowanej atmosferze w zależności od sposobu pakowania i czasu przechowywania chłodniczego

STRESZCZENIE

Przeprowadzono ocenę właściwości fizykochemicznych oraz określono zawartość ogólnej liczby drobnoustrojów w mięśniach piersiowych indyczek przechowywanych w atmosferze gazów kontrolowanych o składzie 95% azotu i 5% tlenu w temp. 2°C oraz w czasie od 5 do 20 dób. Badano mięśnie opakowane w folię typu Nordfilm-Nordform oraz bez opakowania. Rezultaty badań wykazały, że w miarę wydłużania czasu przechowywania wzrastało stopniowo pH mięśni oraz postępowało ciemnienie ich barwy. Te niekorzystne zmiany jakości nieco wolniej przebiegały w mięśniach opakowanych w folię niż w mięśniach przechowywanych bez opakowania. Podobne prawidłowości stwierdzono w kształtowaniu się świeżości lipidów śródmięśniowych określanych na podstawie liczby kwasowej. Ocena jakości mikrobiologicznej mięśni dokonana na podstawie ogólnej liczby drobnoustrojów w 1 g wykazała, że stopień zanieczyszczenia mikrobiologicznego był zadowalający w opakowanych mięśniach piersiowych przechowywanych w atmosferze gazów kontrolowanych przez okres 20 dób i w nieopakowanych w czasie 10 dób.