APARATURA
BADAWCZA I DYDAKTYCZNA

The influence of frozen storage duration and thawing methods on the meat quality of broiler chickens

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Keywords: frozen storage, thawing, meat quality, breast muscles

SUMMARY:

The objective of the study was to assess the influence of frozen storage duration and thawing methods on the breast meat quality of broiler chickens. The study material consisted of breast muscles obtained directly after slaughtering of 36-day old ROSS 308 broiler chickens, subjected to freezing at -18°C and were stored frozen for 1 month as well as for 7 months. The samples were thawed both in open air and water at 4°C. Having been thawed both the raw breast muscles and thermally treated ones were subjected to physicochemical analysis comprising of freezing leakage, pH (Hanna HI99163 ph meter), meat colour using the CIE L*a*b* system (Konica Minolta, Japan), cutting force (Zwick/Roell resistance testing machine, Germany), total protein using Kjeldahl method (Foss Tecator, Sweden), and thermal loss. The influence of freezer storage duration and thawing methods on the degree of cutting force as well as on the brightness parameter (brightness L* and yellow colouration b*) was demonstrated. Lower cutting force (of 2.93 N using atmospheric air and 1.61 N using water methods), including a lower brightness indicator and higher degree of saturation of yellow colouration were characteristics of breast meat subjected to prolonged freezer storage period. A prolonged freezer storage period impacted negatively on the volume of freezing leakage. Both the duration of freezer storage and the thawing method impacted on the volume of thermal loss. The least thermal loss (20.67%) was characteristic of breast meat stored for 1 month and later thawed in atmospheric air. Similar dependencies regarding colouration and cutting force were observed during the evaluation of breast meat stored frozen and subjected to heat treatment.

Wpływ czasu przechowywania zamrażalniczego i metody rozmrażania na jakość mięsa kurcząt brojlerów

Słowa kluczowe: przechowywanie zamrażalnicze, rozmrażanie, jakość, mięśnie piersiowe

STRESZCZENIE:

Celem pracy była ocena wpływu czasu zamrażalniczego przechowywania i metody rozmrażania na jakość mięśni piersiowych kurcząt brojlerów. Surowcem do badań były mięśnie piersiowe pozyskane bezpośrednio po uboju od 36-dniowych kurcząt brojlerów ROSS 308, które poddano zamrożeniu w temperaturze -20°C i przechowywano w warunkach zamrażalniczych przez 1 miesiąc oraz przez 7 miesięcy. Próbki rozmrażano w powietrzu oraz w wodzie, w temperaturze 4°C. W ocenie cech fizykochemicznych mięśni piersiowych surowych i poddanych obróbce termicznej uwzględniono: wyciek rozmrażalniczy, pH (pehametr Hanna HI99163), barwę mięśni w systemie CIE L*a*b* (Konica Minolta, Japonia), siłę cięcia (maszyna wytrzymałościowa Zwick/Roell, Niemcy), białko ogólne metodą Kjeldahla (Foss Tecator, Szwecja), wyciek termiczny. Wykazano wpływ czasu przechowywania zamrażalniczego i metody rozmrażania na wielkość siły cięcia oraz parametry barwy (jasności L* i barwy żółtej b*). Niższą siłą cięcia (o 2,93 N w metodzie powietrznej i 1,61 N w metodzie wodnej) oraz niższym wskaźnikiem jasności i wyższym stopniem wysycenia barwy żółtej charakteryzowały się mięśnie piersiowe po dłuższym okresie przechowywania zamrażalniczego. Dłuższy czas przechowywania zamrażalniczego niekorzystnie wpłynął na wielkość wycieku zamrażalniczego. Zarówno czas przechowywania zamrażalniczego, jak i metoda rozmrażania miały wpływ na wielkość wycieku termicznego. Najmniejszym wyciekiem termicznym (20,67%) cechowały się mięśnie piersiowe przechowywane przez miesiąc i rozmrażane w powietrzu. W ocenie mięśni piersiowych przechowywanych zamrażalniczo i poddanych obróbce termicznej dla barwy i siły cięcia wykazano podobną zależność jak dla mięśni surowych przechowywanych zamrażalniczo.

1. INTRODUCTION

Freezing is a commonly accepted method of preserving poultry meat, enabling the retention of the product's good quality over a prolonged period of time [1, 11]. Moreover, both freezing and frozen storage allows for the economy of surplus raw meat [9].

The quality of frozen meat depends on both the initial pre-freezing as well as later changes that took place at various stages of the freezing and storage process. Hence only high quality raw meat with good processing, technological and sensory properties should be subjected to freezing [2, 9]. The freezing process does not, however, constitute the most significant factor affecting the final quality of frozen meat. The condition of the frozen storage and thawing methods are also important [11, 14]. The duration of frozen storage is constrained by unfavourable physical, chemical and microbiological process that become more intensified during storage [1, 9].

The thawing procedure constitutes the last stage of the freezing technology, aimed at restoring best possible properties as in fresh meat [11, 14]. The quality of thawed meat depends, to a large extent, on the chosen thawing method. The most commonly applied thawing method in homes is thawing in fridges at 4°C, in open air and in water. The aim of the study was to assess the impact of frozen storage duration and thawing methods on the breast muscles quality of broiler chickens.

2. MATERIAL AND METHODS OF RESEARCH

The research material were breast muscles obtained directly after slaughtering not younger than 36-day old ROSS 308 broiler chickens. The slaughtering was conducted at a local commercial slaughter house. The samples (n=60, average mass of 200 ±50 g) were transported in refrigerated containers to the Poultry Products Evaluation Laboratory, then weighed, labelled and packed in polyethylene bags. The meat packs were subjected to freezing at -20°C and were stored frozen in drawer type freezers (GN 3056, Liebherr, Germany) for 1 month (group I) and 7 months (group II). After the set period of freezing, the samples from

group I (n=30) and group II (n=30) were thawed in open air (P) in a refrigerated cabinet (FKv 36110, Liebherr, Germany) and in water at 4°C ±1°C (W) while remaining in the bags until the attainment of a temperature of 4°C ±1°C.

The post thawing assessment of raw breast muscles covered the amount of thaw leakage, pH, protein content, instrumental measurement of colour and cutting force.

The amount of thermal loss was determined by inserting the samples on a cuvette fitted with a 5 mm thick grid spacer to prevent the leakage from getting in contact with the sample. The amount of leakage was calculated by the difference in weight prior and after the freezing process using the formula:

$$W_r(\%) = \left(\frac{M_1 - M_2}{M_1}\right) \times 100\% \quad (1)$$

where:

W_r – the amount of thawing loss [%],

M_1 – sample weight prior to thawing [g],

M_2 – sample weight after thawing [g].

The pH measurements were conducted using a ph meter fitted dagger electrode, HI99163, Hanna. The nitrogen content was determined using Kjeldahl method (Foss Tecator, Höganäs, Sweden), and converted to protein using a multiplaying factor of 6.25. The colour of the raw meat's cross-section was assessed using the Chrome Meter colorimeter (Konica Minolta Osaka, Japan), fitted with a CR 400 head set at illumination levels compatible with D_{65}. The readings of measurement results and their conversion in real time was achieved in the CIE L*a*b* colorimetric system, where L* represents brightness, a* red, and b* yellow. Three repetitions were performed for each sample. The tenderness was assessed by measuring the cutting force (F_{max}), using the Zwick/Roell BT1-FR1.OTH.D14 resistance machine (Zwick GmbH & Co. KG, Ulm, Germany), using a Warner-Bratzler V-blade knife with a head speed of 100 mm··min^{-1} and initial force of 0.2 N. Meat portions with cross-sectional diameter of 100 mm^2 and 50 mm in length were subjected to cutting.

The amount of thermal leakage was determined by subjecting the pre-weighed meat samples to heat treatment in a warm water bath at 70 ±2°C over a 30 minutes period. The samples were after cooling re-weighed. The volume of leakage was calculated using the formula:

$$W_c = \left(\frac{M_I - M_{II}}{M_I}\right) \times 100\% \quad (2)$$

where:

W_c – amount of thermal loss (%),

M_I – weight of samples prior to heat treatment (g),

M_{II} – weight of samples after cooling (g).

Breast muscles portions of similar sizes were weighed to the nearest 0.1 g and subjected to thermal treatment by cooking with a water/meat ratio of 1:2. The thermal treatment was performed until the attainment of meat's internal temperature of 80 ±2°C. The meat's internal temperature was measured with a digital probe thermometer. The assessment of physicochemical properties of all samples was carried out in ways similar to the procedure with raw meat.

The results obtained were statistically analysed using the Statistica 12.0 program, taking account of the arithmetic mean ($\bar{x}$), standard deviation (SD), standard mean error (SEM), and the principal effect, namely (C – impact of storage duration, R – thawing method, C × R – impact of storage duration and thawing method), using the two-way analysis of variance ANOVA. The significance of differences between the mean values within groups was verified using the Tukey's test. Statistically significant differences were assumed at a significance level of $p \leq 0.05$, while the lack of significance was designated with „ns" (statistically insignificant).

3. RESEARCH RESULTS AND DISCUSSION

The effect of frozen storage duration and thawing methods on the physicochemical properties of raw breast muscles is presented in Table 1. The current studies have shown that the pH value of breast muscles decreases with the prolongation of the frozen storage. Results obtained by Ali et al. [2], Chen et al. [8] and Wei et al. [19] have indicated significant declines in pH values in subsequent weeks of frozen storage. Santos Kumar et al. [16], however, noted rising pH values of breast muscles of broiler chickens obtained from varied sources. Chwastowska-Siwiecka [9] provides that pH value of chicken breast muscles decreases along with the prolongation of the frozen storage period. Proteolytic processes associated with prolonged and improper thawing of meat usually lead to increased pH values of thawed meat tissues [11, 14].

Table 1 Effect of frozen storage duration and thawing methods on the physical and chemical features of raw breast muscles ($\bar{x}$ ± SD)

Trait	Frozen storage duration				SEM	C	R	C × R
	1 month (1 group)		7 months (2 group)					
	P	W	P	W				
pH	5.98 ±0.16	6.01 ±0.11	5.82 ±0.10	5.89 ±0.11	0.01	ns	ns	ns
Thawing loss (%)	3.05 ±0.45	3.00 ±0.56	5.00 ±1.39	4.86 ±1.51	0.22	*	ns	ns
Colour L*	50.39 ±2.89	53.92 ±3.01	49.95 ±2.18	50.65 ±2.93	0.29	*	*	ns
a*	1.64 ±0.78	1.59 ±0.58	1.58 ±0.62	1.52 ±0.41	0.07	ns	ns	ns
b*	6.80 ±1.67	6.01 ±1.06	8.97 ±1.31	7.42 ±1.24	0.16	*	*	ns
Shear force (N)	14.96 ±1.07	16.41 ±1.64	12.03 ±1.33	14.80 ±2.08	0.22	*	*	ns
Crude protein (%)	23.60 ±0.71	23.56 ±0.84	23.89 ±0.80	23.72 ±0.66	0.03	ns	ns	ns

P – breast muscles thawed in open air at 4°C, W – breast muscles thawed in water at 4°C, C – impact of frozen storage duration, R – impact of freezing method, C × R – impact of frozen storage duration and freezing method, * – statistically significant differences p≤0.05; ns – differences statistically insignificant

The amount of thaw leakage is a primary indicator of meat quality after the freezing process [1], and it depends on the type and size of the raw meat, freezing method, conditions of the frozen storage and thawing methods used [3, 7, 17, 19]. High values of thermal losses testify to the irreversible loss of valuable nutrients [1]. The current study has indicated significant impact (p≤0.05) of the frozen storage duration on the amount of thermal loss. The results obtained for open air thawed samples correspond to those obtained by Ali et al. [3]. Lower value of this indicator, but with similar incremental tendency of thaw leakages along with an 8-month frozen storage duration were demonstrated by Wei et al. [19]. Śmiecińska et al. [18], however, observed lower values of thermal loss for turkey breast muscles, that was stored frozen for 6 weeks.

Meat colour is a key qualitative characteristics of meat freshness and suitability for culinary purposes [5, 10, 13]. The degree of colour change of frozen meat is dependent mainly on the availability of atmospheric oxygen as well as on the conditions of frozen storage [4]. The instrumental assessment of the colouration of post-thawed raw breast muscles indicated a significant influence (p≤0.05) of storage duration and thawing methods on the colour of breast muscles. A decrease in the brightness parameter (L*) and increase intensity of yellow (b*) was observed along with the increasing freezing duration. The results obtained correspond with studies by Wei et al. [19]. Galobart & Moran [10] and Ali et al. [3], on the other hand, demonstrated the influence of shorter frozen storage duration on the increase of the brightness L* and yellow parameters of breast muscles thawed in open air. The current study has indicated that darker colouration (lower brightness parameter) as well as higher intensity of yellow were characteristic of breast muscles thawed in open air in comparison to thawing in water. These findings are comparable to those obtained in studies by Benli [5], using similar thawing methods. A similar trend was demonstrated by Kim et al. [12] in studies conducted on pork meat.

The current study confirms the significant (p≤ 0.05) impact of both the duration of the freezing state and thawing methods on the fragility of raw breast muscles as indicated by the cutting force. It is demonstrated that the cutting force of raw breast muscles increases proportionately

with the duration of the frozen storage period. These findings were corroborated by Chen et al. [8]. Changes to the meat's texture and deterioration of its fragility are likely during the frozen storage. The changes during this period may be due to protein changes in the meat tissues as well fluid losses during the thawing process, which results in less humidification of tissue fibres [5, 14, 19]. The tenderness of poultry meat measured by the cutting force depends, according to Oliveira et al. [15], on the thawing methods. The current study demonstrated that lower cutting force was characteristic of raw breast muscles thawed in open air in comparison that thawed in water, which could be due to the loss of fluids during the thawing process [14].

The current study did neither indicate any significant ($p \geq 0.05$) impact of the frozen storage duration nor the thawing method on the crude protein content in raw breast muscles. Akhtar et al. [1], Chan et al. [6] and Gambuteanu et al. [11] opine that protein transformations during normal thawing processes are insignificant and limited to slight protein and amino-acids losses associated with thaw leakages.

A significant ($p \leq 0.05$) influence of storage duration, thawing methods, including their interactions on the volume of thermal loss was observed (Tab. 2). It was demonstrated that the prolongation of the storage period resulted in increased volume of thermal loss, which was higher in meat thawed in water. Comparable relationship for an 8-month long frozen storage duration was noted by Wei et al. [29]. Chen et al. [7] and Śmiecińska et al. [18], however, observed a slight decrease in thermal loss during the last freezing cycle. Studies conducted by Benli [5] demonstrated the impact of thawing methods on the amount of thermal loss, thus corroborating the findings of the current study. Higher thermal loss was typical of breast muscles thawed in water in comparison to thawing in open air. Similar trends of the thawing method in question was observed in studies into pork meat by Kim et al. [12]. Yu et al. [20] stated that differences in the amount of thermal loss depended on the thawing temperature. The volume of thermal loss has an enormous impact on the quality properties of culinary meat and yield of finished products [5, 11].

The current studies have indicated significant ($p \leq 0.05$) impact of frozen storage duration on the colour parameters of post thermally treated breast muscles (Tab. 2). The darker colouration of the meat was observed, namely reduction of the brightness parameter (L*) as well as the increased saturation of red a* and yellow b*

Table 2 Effect of frozen storage duration and freezing methods on the physical and chemical features of cooked breast muscles ($\bar{x} \pm SD$)

Trait	Frozen storage duration				SEM	C	R	C × R
	1 month (1 group)		7 months (2 group)					
	P	W	P	W				
Weight loss (%)	20.67 ±0.67	23.05 ±0.72	22.83 ±0.35	24.58 ±0.42	0.08	*	*	*
Colour								
L*	83.93 ±0.95	82.30 ±1.76	81.08 ±0.58	70.41 ±1.33	0.65	*	ns	ns
a*	1.47 ±0.36	1.54 ±0.31	1.67 ±0.67	1.69 ±0.11	0.05	*	ns	ns
b*	10.95 ±1.02	10.51 ±0.69	13.18 ±0.66	12.72 ±0.85	0.10	*	ns	ns
Shear force (N)	17.47 ±1.26	18.38 ±1.18	16.16 ±1.04	16.87 ±1.06	0.24	*	ns	ns
Crude protein (%)	30.87 ±0.69	29.74 ±0.47	30.66 ±0.78	30.44 ±0.55	0.14	ns	ns	ns

P – breast muscles thawed in open air at 4°C, W – breast muscles thawed in water at 4°C, C – impact of frozen storage duration, R – impact of freezing method, C × R – impact of frozen storage duration and freezing method, * – statistically significant differences $p \leq 0.05$; ns – differences statistically insignificant

colours. Results obtained by Galobart and Moran [10] for the L* parameter for frozen stored breast muscles and further subjected to cooking processes were dissimilar. Studies conducted by Benli [5] did not demonstrate the impact of thawing methods on colour parameters after the thermal treatment, a fact that was validated in the current study.

Tenderness is meat's quality feature assessed by consumers in its post thermal treatment stage [5, 13]. The current studies have shown that the frozen storage duration has a significant ($p \leq 0.05$) effect on the magnitude of the cutting force of thermally treated breast muscles (Tab. 2). The tenderness of thermally treated breast muscles diminishes with the duration of frozen storage. Similar findings were obtained by Śmiecińska et al. [18], who conducted studies on the breast muscles of turkeys. The current studies did not demonstrate significant ($p \geq 0.05$) effect of thawing methods on the magnitude of the cutting force of meat. Oliveira et al. [15] have in their studies indicated lower cutting force of breast muscles thawed in water in comparison to that thawed in open air. Yu et al. [20] demonstrated the effect of thawing temperature on the magnitude of cutting force of breast muscles.

4. CONCLUSIONS

The significant ($p \leq 0.05$) impact of frozen storage duration on the amount of thermal loss, colours and cutting force of raw breast muscles was demonstrated. Longer periods of frozen storage resulted in intensified thermal loss, darker colouration (lower L* parameter and higher yellow saturation b*) as well as lower cutting force. The breast muscles thawed using air method was characterized by significantly lower brightness L* parameter, higher saturation of yellow colour and lower cutting force in comparison to breast muscles thawed in water.

Both the frozen storage duration and the thawing method had impacts on the volume of thermal loss. Significantly ($p \leq 0.05$) greater thermal losses were identical with breast muscles stored over a 7 month period and thawed in water. The colour assessment and cutting force of breast muscles that was subjected to frozen storage and thermal treatment showed relationships similar to frozen stored raw meat.

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