APARATURA
BADAWCZA I DYDAKTYCZNA

Effects of thawing methods on the physicochemical properties of freezer stored broiler chicken breast muscles

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Keywords: breast muscles, freezing storage, thawing methods, physicochemical properties

SUMMARY:

The aim of the paper was to evaluate the influence of thawing methods on the physicochemical properties of freezer stored breast muscles of broiler chickens. The microwave thawing method was compared with traditional methods of thawing meat in atmospheric air and water conditions. The research material consisted of breast muscles obtained directly after slaughtering of 35-day old Ross 308 broiler chickens, subjected to freezing at -20^{o}C and stored frozen for 5 weeks. The samples were thawed until the temperature in the centre of the meat reached to 4^{o}±1^{o}C. The quality of breast muscles before and after the freezing process was assessed. In the assessment of the physicochemical properties of raw breast muscles (thawing loss, pH, colour, shear force and chemical composition) and after cooking (weight loss, colour, shear force and chemical composition) were taken into consideration. It was demonstrated that the thawing of broiler chicken breast muscles using microwave methods had positive impacts on the volume of thaw leakage, as well as the ash content of raw meat that had been subjected to thermal treatment. Breast muscles thawed by microwave methods was, compared with other commonly applied thawing methods, characterized by more intensive red colour (a*) saturation, a situation comparable to meat colouration prior to its freezing. A higher cutting force (less brittleness) was, compared to that thawed in atmospheric air and water, characteristic of breast meat thawed using microwave methods. The study demonstrated that the brittleness of frozen breast meat and subjected to thermal treatment retained a trend similar to that of raw meat.

Wpływ metod rozmrażania na cechy fizykochemiczne przechowywanych zamrażalniczo mięśni piersiowych kurcząt brojlerów

Słowa kluczowe: mięśnie piersiowe, zamrażalnicze przechowywanie, metody rozmrażania, cechy fizykochemiczne

STRESZCZENIE:

Celem pracy była ocena wpływu metod rozmrażania na cechy fizykochemiczne przechowywanych zamrażalniczo mięśni piersiowych kurcząt brojlerów. Porównano mikrofalową metodę rozmrażania mięśni piersiowych z tradycyjnymi metodami rozmrażania w warunkach powietrza atmosferycznego i wody. Surowiec do badań stanowiły mięśnie piersiowe pozyskane od 35-dniowych kurcząt brojlerów Ross 308, poddane zamrażaniu w temperaturze -20°C i przechowywane w warunkach zamrażalniczych przez 5 tygodni. Próbki rozmrażano do temperatury wewnątrz mięśnia 4°C±1°C. Oceniono jakość mięśni piersiowych przed i po procesie zamrażania. W ocenie parametrów fizykochemicznych surowych mięśni piersiowych uwzględniono (wyciek rozmrażalniczy, pH, barwę, siłę cięcia, skład chemiczny), po obróbce termicznej (wydajność produktu, barwę, siłę cięcia, skład chemiczny). Wykazano, że zastosowanie mikrofalowej metody rozmrażania mięśni piersiowych kurcząt brojlerów korzystnie wpłynęło na wielkość wycieku rozmrażalniczego i zawartość popiołu w mięśniach piersiowych surowych i poddanych obróbce termicznej. Mięśnie piersiowe rozmrażane metodą mikrofalową w porównaniu do powszechnie stosowanych metod rozmrażania charakteryzowały się wyższym stopniem wysycenia barwy czerwonej (a*), który był porównywalny do barwy mięśni piersiowych przed procesem mrożenia. Wyższą siłą cięcia (gorszą kruchością) cechowały się mięśnie piersiowe rozmrażane metodą mikrofalową w porównaniu do mięśni piersiowych rozmrażanych w powietrzu i w wodzie. Wykazano, że kruchość mięśni piersiowych rozmrażanych i poddanych obróbce termicznej zachowała podobną tendencję, jak w przypadku mięśni surowych.

1. INTRODUCTION

Freezing is a commonly applied method that retains the high quality and durability of perishable meat [1, 16]. In addition, both freezing and freezer storage technologies are irreplaceable in raw meat management, especially at times of surplus market supply. Thawing is the last stage of refrigeration technology aimed at restoring the meat's properties to, as close as, that of fresh meat. Any impropriety in the thawing process can contribute to the deterioration of its quality [9, 10, 15].
Commonly applied traditional thawing methods, such as cold water thawing, atmospheric air thawing and refrigerator thawing, could result in poor meat quality due to longer time duration and higher temperature difference between its inside and outside [4, 17]. The increasing market share of deep-frozen raw meat for culinary or processing purposes has resulted in the need to apply modern methods of thawing meat. This criterion is fulfilled by microwave thawing method. Microwave radiation causes high uniform heating of the entire mass of the thawed meat as well as reduction of the thawing time to just a few minutes. It allows for a better control of the parameters and reduction of risks from microbial contamination [6].
The aim of the paper was to evaluate the influence of thawing methods on the physicochemical properties of freezer stored breast muscles of broiler chickens. The microwave thawing method was compared with traditional methods of thawing meat in atmospheric air and water conditions.

2. MATERIALS AND RESEARCH METHODS

The research material consisted of breast muscles, free of skin and subcutaneous fat obtained from 35-day old Ross 308 broiler chickens. The birds were slaughtered mechanically in production conditions at a local slaughterhouse. The birds were soon after the blood-letting and scalding subjected to plucking and evisceration, followed with a two-staged chilling process, both in water up to 16°C and air-jet method to achieve 2°C internal meat temperature. The broiler chicken carcasses were transported in refrigerated conditions to the laboratory of the Department of Animal Production and Poultry Products Evaluation and stored at a temperature of 4°C over a 24-hour period. They were, then, dissected from which 30 double breast muscles parts were prepared. Every meat portion was weighed and the samples for analysis as chilled meat were identified (n=30), while those for freezing (n=30) were packed in polyethylene bags. The samples were stored in deep freeze conditions with stable parameters (temperature at -20°C and 18.5% humidity) in drawer freezer type GN 3056 Liebherr company, Germany for 5 weeks. The samples were thawed in drawer freezer type FKv 36110 from Liebherr company, Germany in atmospheric air (n=10) and in water (n=10) at 4°C to achieve a temperature of 4°C±1°C without removing them from the bags, as well as by using microwave method (n=10). Microwave thawing involved placing the samples in a type 29Z013, 800 W, of Zelmer Company, Poland microwave equipment and subjecting them to electromagnetic waves over a 5 minute period. The post thawing internal temperature of the meat was 0°C±1°C, but was 5°C±1°C on its outer layer. The internal temperature of the samples was subsequently raised to 4°C±1°C.

The laboratory assessment of chilled breast muscles, following their freezing process and the relevant thawing method covered its pH, water absorption, colour, meat brittleness, as well as protein, fat and ash contents. All measurements were conducted in three repetitions. The pH measurement was conducted using a dagger electrode connected with a pH meter (HI 99163 from Hanna). The water-holding capacity (WHC) was determined based on the volume of free water squeezed from the samples using the Whatman no 2 filter paper method of Grau and Hamm. The colour evaluation of the cross-sectional surface of raw meat was achieved using the Chrom Meter (Konica Minolta Osaka, Japan) colorimeter with a CR 400 head, set to an illumination level compatible with the D_6. illuminator. The readings were carried out using the CIE LAB colorimetric system, with coordinates L* (brightness), a* (red) and b* (yellow). The brittleness test was carried out on samples measuring 10 mm × 10 mm × 50 mm, cut parallel to the muscle fibres. In order to measure the cutting force the (F_{max}) Zwick/Roell BT1-FR1.OTH.D14 (Zwick GmbH & Co. KG Ulm, Germany) resistance testing machine was used, fitted with a single-blade cutting system from Warner--Bratzler (one 1.2 mm thick flat blade having a triangular 60° point of incision, whose interior edge is also the working edge). It has a head speed of 100 mm··min^{-1} and initial force of 0.2 N. The cutting was at an angle perpendicular to the direction of meat fibres. The results of the cutting force measurements were analysed using the Test Xpert II software. The nitrogen content was determined using the Kjeldahl (Foss Tecator kit, Hőganäs, Sweden) method and converted into protein, multiplying the result by a factor of 6.25 [18]. The fat content was ascertained using Soxhlet (Büchi Extraction System B-811 apparatus, Flawil, Switzerland) method. The samples (5 g±0,001 g) previously dried at 105°C were subjected to extraction using n-hexan as a solvent. The amount of fat was determined by weighing, after the solvent had been extracted [19]. Total ash content was determined following the mineralisation of 5 g of meat sample at 550-650°C, using a Carbolite muffle furnace AAF1100, Hope Valley, UK [20]. The amount of leakage was calculated by the difference in weight before freezing and after thawing process using the formula:

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

where: W_r – the amount of drip loss (%), M_1 – sample weight before freezing (g), M_2 – sample weight after thawing (g).

In order to evaluate the physicochemical parameters of breast muscles prior to and after the freezing process and further subjected to thermal treatment, the samples were boiled in water (ratio of meat weight / water was 1:2) to achieve the meat's internal temperature of 75°±2°C. The assessment of the physicochemical characteristics were carried out in ways similar to that for raw breast muscles. Weight losses were calculated based on the difference in weight before and after the thermal treatment.

Arithmetic means ($\overline{xx}$) and standard deviations (s) were determined, and the significance of differences between the mean values of the analyzed parameters in groups (subject to the applied thawing method) was estimated by Ducan's test, using STATISTICA ver. 12.0 PL software.

3. RESULTS AND DISCUSSIONS

Thawing loss is a significant indicator of the quality of meat subjected to freezing storage [10, 12, 16]. It is assumed that the volume of meat drip leakage during thawing by use of various methods could serve as a measure of the degree of damage to the meat's structural tissues during freezing and can also be an indirect assessment of various thawing methods [11, 15]. The current studies have indicated that significantly ($p \leq 0.05$) lower drip loss is typical of breast muscles, thawed using microwave method compared to meat thawed in atmospheric air and water (Tab. 1). Short-term microwave thawing probably resulted in less damage to cell structures, thus leading to less water loss [4]. The results obtained are similar to those obtained in studies conducted by Kim et al. [13] on beef meat using the same thawing methods as well as Chwastowska and Kondratowicz [7] on pork meat thawed using both atmospheric air and microwave.

The primary parameter for assessing meat quality is the degree of its acidification [3]. The current study did not observe any significant ($p>0.05$) influence of thawing methods on the pH value (Tab. 1), which testifies of the good quality of the initial material and the propriety of the freezing storage conditions. The current studies showed that freezer storage had significant ($p \leq 0.05$) impact on the increased water holding capacity of breast muscles (Tab. 1). Higher amount of drip loss during freezing storage limited the amount of forced leakage from meat, which could be a pointer to the better water holding capacity of meat stored frozen over a 5-week period, irrespective of the thawing method applied. The results obtained are similar to those achieved by Wei et al. [22] carried out on broiler chickens breast muscles prior to the freezing as well as after 4 weeks of freezing storage, including those of Śmiecińska et al. [21] conducted on turkeys breast muscles prior to freezing and after 2 weeks of freezing storage. The current studies have shown that thawing methods have no significant ($p>0.05$) on the amount of forced leakages from meat.

The meat colour is an important quality characteristic that determines the freshness of meat and its suitability for culinary purposes. The meat of broiler chickens soon after freezing contains mainly oxymyoglobin and oxyhemoglobin (about 51%) as well as metmyoglobin and methemyoglobin (about 13%). Low temperature is a factor that inhibits the oxidation of pigments, although it does not stop the process entirely [1, 6, 10]. The current studies (Tab. 1) have indicated a significant ($p<0.05$) influence of thawing methods on the intensity of colour saturation towards red (a*) and yellow (b*) in breast muscles subjected to thermal treatments. A higher intensity of red colour saturation (a*) was characteristic of breast muscles thawed in atmospheric air and in water. Similar values for the red parameter (a*) were obtained by Kim et al. [11], having thawed broiler chickens breast muscles using the microwave method. The studies indicated that the intensity of red colour saturation (a*) in raw meat, thawed using the microwave method was similar to the red colour saturation of breast muscles prior to its freezing (Tab. 1). It was also demonstrated that the brighter colouration, including the sig-

Table 1 Influence of thawing methods on the physicochemical parameters of raw breast muscles ($\bar{x} \pm s$)

Specification	Chilled muscles	Frozen muscles		
		thawing method		
		microwave oven	atmospheric air	cold water
Thawing loss (%)	-	$2.98^b \pm 0.18$	$3.64^a \pm 0.30$	$3.86^a \pm 0.30$
pH	6.00 ± 0.08	5.92 ± 0.06	5.98 ± 0.09	5.97 ± 0.10
WHC (%)	$13.61^b \pm 1.28$	$16.06^a \pm 1.42$	$15.98^a \pm 1.26$	$15.65^a \pm 1.34$
Colour:				
L* – lightness	53.00 ± 2.41	52.12 ± 2.50	53.31 ± 2.20	53.98 ± 2.40
a* – redness	$1.97^b \pm 0.54$	$1.92^b \pm 0.62$	$1.68^a \pm 0.52$	$1.36^a \pm 0.48$
b* – yellowness	$3.46^b \pm 0.96$	$6.55^a \pm 1.32$	$6.04^a \pm 1.20$	$4.87^b \pm 1.18$
Shear force (N)	$17.04^b \pm 2.46$	$16.54^b \pm 1.98$	$14.11^a \pm 2.50$	$15.05^a \pm 1.98$
Crude protein (%)	23.68 ± 1.10	23.84 ± 1.04	23.78 ± 1.11	23.74 ± 0.98
Fat (%)	$1.21^b \pm 0.18$	1.19 ± 0.11	$1.17^a \pm 0.14$	1.18 ± 0.11
Ash (%)	$1.14^a \pm 0.10$	$1.19^b \pm 0.12$	$1.15^a \pm 0.11$	$1.13^a \pm 0.12$

a, b – values with different superscript letters are significantly differences $p \leq 0.05$

nificantly (p≤0.05) lower intensity of yellow colour saturation (b*) were typical of meat thawed in water compared to other methods of thawing. Likewise, the studies conducted by Kim et al. [13] on pork meat demonstrated that the brighter colouration was characteristic of raw material thawed in water. Significantly (p≤0.05) higher yellow colour saturation was typical of raw breast muscles thawed using both microwave and atmospheric air methods, compared to the breast muscles prior to its freezing. Freezing storage resulted in increased intensity of yellow colour saturation, which was confirmed in studies conducted by Galobart and Moran [9] as well as Zhang et al. [23].

Changes in the colour of breast muscles prior to and after freezing and subjected to thermal treatments are shown in Table 2. The current studies have demonstrated the existence of statistically significant differences between the influence of microwave and atmospheric air methods of thawing on the intensity of red colour saturation (a*), while maintaining tendencies similar the raw meat. The frozen stored source material that had been subjected to thermal treatment was characterized by higher yellow colour saturation (b*), irrespective of the thawing methods applied compared to results of samples not subjected to freezing processes.

Changes to the meat brittleness during frozen storage could be attributed to changes in the tissues of meat protein [14]. The thawing method, according to Gambuteanu et al. [10], can have impacts on the meat's brittleness. This was similarly observed in the current study (Tab. 1 and Tab. 2). A significantly (p≤0.05) less cutting force was characteristic of breast muscles thawed in atmospheric air and in water, compared to that thawed using the microwave method, evaluated prior to and after the thermal treatment. The obtained results are comparable to those obtained for the cutting force for broiler chickens breast muscles using the same thawing methods described in the work of Oliviera et al. [17]. Similar findings were obtained by Śmiecińska et al. [18] in their studies on the turkey breast muscles. Freezing storage, according to Farouk et al. [8] increases the brittleness of meat, especially in respect of poultry meat not subjected to maturity processes.

The current studies demonstrated similar tendencies of changes in nutrients both in thawed raw breast muscles as well as in those subjected to thermal treatment (Tab. 1 and Tab. 2). Protein changes during thawing, according to Gambuteanu et al. [10], that take place in typical conditions are not significant, and are very often limited to insignificant losses of proteins and amino-acids caused by the drip loss. The current study did not indicate a significant (p>0,05) impact of freezing duration and thawing methods on crude protein content. While studying the impact of microwave thawing on the meat's chemical content, Kim et al. [11] did not demonstrate the influence of thawing methods (the intensity of radiation) on the protein content of breast muscles. Bustamante-Vargas et al. [2] noted that higher protein loss in raw breast muscles was observed during thawing using the microwave method compared to

Table 2 Influence of thawing methods on the physicochemical parameters of breast muscles subjected to thermal treatment ($\bar{x} \pm s$)

Specification	Chilled muscles	Frozen muscles		
		thawing method		
		microwave oven	atmospheric air	cold water
Weight loss (%)	24.59±1.25	24.43±1.42	23.56±1.13	24.17±1.58
Colour:				
L* – lightness	80.06±1.20	80.65±1.52	81.12±1.45	81.82±1.45
a* – redness	1.54^b±0.45	1.48^b±0.28	1.32±0.42	1.12^a±0.42
b* – yellowness	8.96^b±1.02	12.92^a±1.12	12.86^a±1.00	11.44^a±1.30
Shear force (N)	20.88^b±2.80	19.81^b±2.68	17.88^a±2.85	18.10^a±2.85
Crude protein (%)	29.52±0.80	30.54±0.83	29.95±0.71	29.85±0.71
Fat (%)	1.23±0.14	1.25±0.12	1.26±0.16	1.24±0.16
Ash (%)	1.28±0.14	1.30^b±0.10	1.25^a±0.15	1.24^a±0.15

a, b – values with different superscript letters are significantly differences p≤0.05;

thawing, using atmospheric air and water, alongside a large thaw leakage. The current study has indicated a significant ($p \leq 0.05$) influence of thawing methods on the ash content in the tested breast muscles (Tab. 1). Higher ash content was typical of breast muscles thawed using the microwave method compared to those thawed using atmospheric air and in water. The lower ash content in these thawing methods may be due to the higher drip loss during thawing and subsequently result in greater loss of minerals. Similar results were obtained by Chwastowska and Kondratowicz [7] in their studies on the influence of thawing methods (atmospheric air and microwave) on the ash content of raw pork meat.

The amount of thermal leakage has a significant influence on culinary features and the yield of the finished product. The current study did not, however, demonstrate the influence ($p > 0.05$) of the thawing methods under study on the amount of thermal loss of breast meat stored in freezers over a 5-week period. Similar results were obtained by Zhang et al. [23], who conducted studies on breast muscles as well as Chwastowska and Kondratowicz [7] on pork meat. Studies conducted by Chen et al. [5], Śmiecińska et al. [21], Wei et al. [22] also indicated that any prolongation of the frozen storage duration necessitates increased thermal loss.

4. CONCLUSION

1. It was demonstrated that the thawing of broiler chicken breast muscles using microwave methods had positive impacts on the volume of thaw leakage, as well as the ash content of raw meat that had been subjected to thermal treatment.
2. Breast muscles thawed by microwave methods was, compared with other commonly applied thawing methods, characterized by more intensive red colour (a*) saturation, a situation comparable to meat colouration prior to its freezing. Lower intensity of yellow colour (b*) saturation was characteristic of raw breast meat thawed in water compared to both atmospheric air and microwave thawing methods.
3. Better brittleness, measured by the cutting force, was typical of raw breast meat thawed using atmospheric air (14,11 N) and in water (15,05 N), compared to breast meat thawed using the microwave method (16,54 N). It has been demonstrated that the brittleness of thawed breast meat and subjected to thermal treatment exhibited similar tendencies as raw meat.

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