COLD CHAIN IMPACT: EVALUATING THE INFLUENCE OF FREEZING AND THAWING ON POULTRY MEAT QUALITY

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RESEARCH ARTICLE

Abstract

The present study sought to investigate the impact of preservation methods, specifically refrigeration and freezing, as well as the storage conditions employed during preservation (wet and dry), on the physico-chemical attributes of chicken breast. Parameters examined included pH, shear force, moisture content, dry matter, protein content, collagen content, and lipid content. For analysis, rapid frozen samples underwent gradual thawing at refrigeration temperatures, adhering to the two storage methods—wet preservation involving vacuum-packed samples and dry preservation involving samples exposed to air currents within the refrigeration enclosure. The results indicated a notable influence of both preservation methods on pH and the total energy required for cutting, with shear force primarily affected by the storage conditions (p<0.0001). Shear force (N) exhibited a discernible correlation with sample firmness, particularly evident in samples stored in a dry environment. The values exhibited a significant decrease, with mean values dropping from 18.6 N (dry refrigerated sample) and 23.8 N (wet refrigerated sample) to 16.8 N (dry thawed sample) and 20 N (wet thawed sample). The impact of the investigated factors on chemical components was found to be minimal. Moisture content exhibited a decrease from 76.84% (wet chilled) and 76.62% (dry chilled) to 76.4% (wet thawed) and 76.38% (dry thawed). Conversely, lipid content showed an increase from a minimum of 0.86% (wet chilled) to 76.38% (dry thawed).

Keywords: chicken breast meat, rapid freezing, chilled vs. thawed meat
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INTRODUCTION

The poultry meat market is characterized by significant growth and diversification, currently ranking first globally in terms of meat consumption at 14.9 kg per capita (OECD, 2023). Poultry meat continues to be a valuable component of the human diet, experiencing consistent growth, particularly in Europe. Fast-growing broilers dominate poultry meat production due to their efficiency in feed utilization. Consumer choices regarding poultry meat are heavily influenced by the nutritional value and sensory characteristics of these products, as well as their relatively low price and varied availability compared to other types of meat and animal products (Augustyńska-Prejsnar et al, 2019).

Freezing is one of the most important methods for preserving meat and meat products, as it results in minimal quality loss during long-term storage compared to other methods (Soyer et al, 2010). Freezing meat to extend its shelf life is a longstanding practice, with significant advances in freezing technology emerging primarily in the last century. Currently, in the global meat export industry, freezing is an essential element in maintaining product safety standards for meat distributed worldwide. However, the impact of freezing and subsequent thawing on meat quality remains a notable concern (Leygonie et al, 2012).

The freezing storage is employed to delay undesirable biochemical reactions in meat and prevent the adverse action of microorganisms and enzymes. However, a drawback of this method is the formation and distribution of ice crystals that influence the meat's structure by causing interruptions in cell integrity and the destruction of muscle fibers. Furthermore, temperature fluctuations in already frozen meat or the frequency of freeze-thaw cycles lead to physiological and biochemical changes in muscular systems, stimulate lipid oxidation, and accelerate the discoloration of the meat surface (Soyer et al, 2010; Ali et al, 2015; Oliveira et al, 2015; Fernandes et al, 2016).

Once subjected to freezing, to ensure the quality of the final product, it is recommended to employ appropriate thawing methods. Generally, slow thawing at low temperatures is recommended (Oliveira et al, 2015).

This study aimed to assess the influence of two slow thawing methods at refrigeration temperature, considering the manner of thawing (wet and dry), on the physico-chemical qualities of chicken breast subjected to rapid freezing (at -27.7°C for 24 hours). Those samples were compared with samples subjected only to refrigeration for preservation.

MATERIAL AND METHOD

The biological material utilized in the study consisted of chicken meat, specifically chicken breast (*musculus pectoralis*), procured from the local market in refrigerated form. The total quantity of purchased chicken meat was divided to undergo the following preservation treatments as outlined in this study:

- Refrigeration with wet storage;
- Refrigeration with dry storage;
- Freezing with wet storage for 24 hours, followed by thawing through wet refrigeration;
- Freezing with dry storage for 24 hours, followed by thawing through dry refrigeration.

The preparation procedures for refrigerated samples involved two distinct methods. The first method entailed storing the samples in vacuum-sealed bags (a medium retaining moisture), followed by vacuuming and placing them in refrigeration chambers at temperatures between 2-4°C. In the second method, the meat sample was placed in refrigeration chambers without being wrapped in plastic bags (dry refrigeration). For the freezing process, a probe thermometer was inserted into the samples to record temperature variations during the freezing process. The samples underwent the same differentiated preparation operations for both wet and dry storage methods. Subsequently, the meat was vacuum-sealed (only in the case of wet freezing) and stored in freezers. The thawing stage was carried out according to the established methodology, by storing the meat in an environment at refrigeration temperatures, either wrapped or unwrapped in a vacuum-sealed package.

The pH of the meat samples was determined using a digital pH meter (HANNA HI 99163), which automatically recorded acidity and temperature values. Prior to conducting acidity measurements on the samples, the pH meter was calibrated using two buffer solutions with known pH values (pH = 4.01 and pH = 7.01). After calibration, the pH meter electrodes were inserted into the previously prepared meat samples, reading the pH in five sampling zones. The instrument electrode was cleaned with distilled water before and after each measurement.

The determination of textural indicators was conducted using a Mark 10 mechanical testing instrument from the United States, equipped with a Mark 10 Series 7 dynamometer, featuring a measurement range between 0 and 1000 N and a resolution of 0.2 N. The testing probe employed was a V knife from WERNER BRATZLER.

Meat samples were extracted using a cylindrical stainless steel probe with standardized dimensions of 6 cm length, 2 cm width, and 25 mm diameter to ensure measurement uniformity. The maximum force required for cutting the cylindrical meat samples was recorded, and the mechanical work or energy consumed in the cutting process was calculated. The testing involved shear force at a knife displacement speed of 200 mm/min, and the resulting data were graphically represented as a force-displacement dependency. Data graphic recording was managed using the MESUREGauge+ program, while data analysis was performed using Excel and GraphPadPrism9 software.

The proximate chemical composition of the meat samples was analyzed using the FoodCheck automatic analyzer, an instrument utilizing infrared spectrometry to examine meat samples by measuring absorption in the infrared spectrum.

For each type of analysis, a minimum of 5 determinations were conducted for each refrigeration and freezing-thawing method applied to the meat. The obtained results were then statistically processed using the XLSTAT program (Addinsoft, 2023), employing the Tukey (HSD) test for analyzing differences between categories, with a confidence interval of 95%.

RESULTS AND DISCUSSIONS

To monitor temperature variations during the freezing process for both storage methods (dry and wet), a thermometer probe was inserted into each meat piece at a depth of 1 cm from the meat surface. Temperature decrease was recorded over a 24-hour period to estimate the freezing rate of the sample (expressed in ºC/cm/h). Depending on the average freezing rate, the freezing process can be categorized as follows: very slow freezing (when the freezing rate < 0.1 cm/h); slow freezing (freezing rate = 0.1 - 0.5 cm/h, especially in air cooling or natural convection); fast freezing (freezing rate = 0.5 - 3 cm/h, using forced convection or air cooling); very fast freezing (freezing rate = 5 – 10 cm/h, using fluidized bed air cooling) (Oliveira et al, 2015).

After completing the freezing of meat samples, they are placed at refrigeration temperature for thawing, with periodic measurements of temperature increase. After 48 hours of monitoring, the average freezing and thawing rates were calculated for each sample. Temperature curves were generated for the freezing phases (Figure 1), to determine the type of freezing (slow or fast), and for the thawing phases (Figure 2).

In the case of wet freezing, the product temperature during freezing decreased from 7ºC to -27.8 ºC over a 24-hour period, resulting in an average temperature decrease of 0.78ºC/h, indicating rapid freezing. In dry freezing, the meat temperature during freezing decreased from 6.6 ºC (at the onset of freezing) to -27.7 ºC over a 24-hour period. The average temperature decrease was 0.70 ºC/h, indicating that the product underwent rapid freezing (Figure 1).

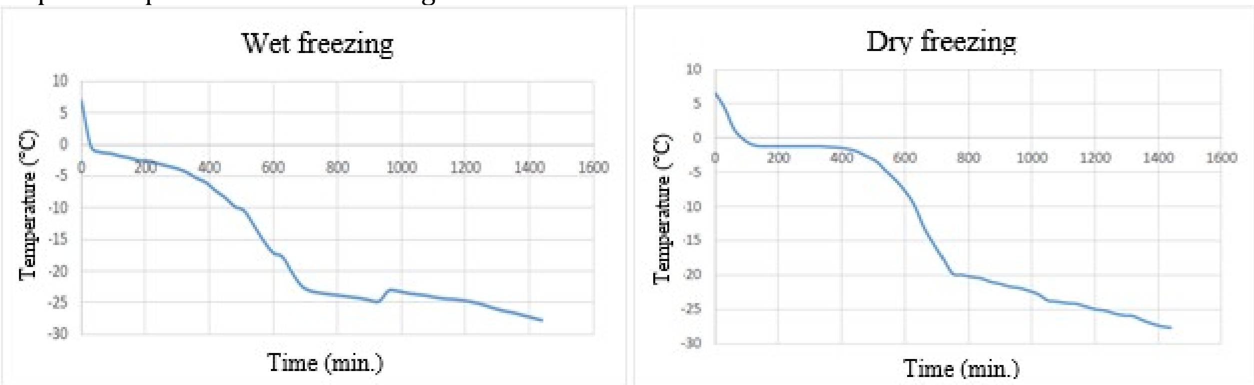

Figure 1 **Temperature graph for freezing chicken**

In the wet thawing step, the sample temperature increases within 24 hours from -27.8ºC to 1.8ºC, on average by 0.74ºC/h. While in the dry thawing the sample temperature increases in the 24 hour interval from -27.7 ºC to 1.9 ºC, on average by 0.61 ºC/h (Figure 2).

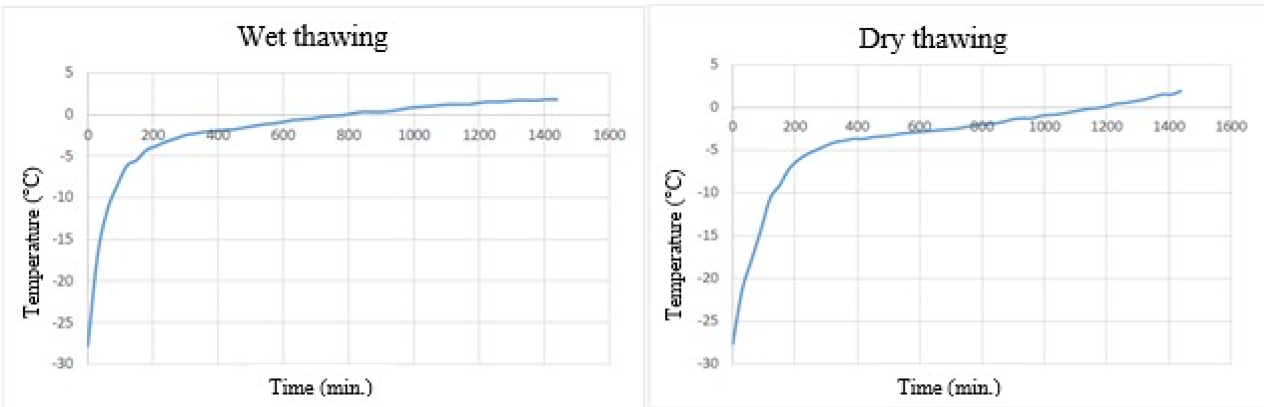

Figure 2 **Temperature graph for thawing chicken**

In the study investigating the influence of preservation type and storage method on chicken meat, physico-chemical properties were monitored, including pH, shear force, total shear energy, as well as water content, dry matter, protein, collagen, and fat.

Table 1 presents the results obtained for the physical parameters for the four chicken breast samples subjected to refrigeration and wet and dry freezing/thawing.

The pH of the chicken breast samples ranged from the average values of 6.10±0.03 (dry refrigerated sample) to 6.38±0.03 (wet thawed sample). Higher pH values were observed for frozen and subsequently thawed meat samples compared to those only refrigerated. According to the literature, the normal pH of chicken meat, particularly in the breast muscle, is in the range of 5.7–5.9 (Fernandes et al, 2016). The average values obtained in the study indicate the development of characteristics consistent with DFD (Dark, Firm, and Dry) in the analyzed chicken meat, both in refrigerated and frozen/thawed samples. Similar results were described by Barbut et al (2005), who reported an average pH value of 6.27 for DFD chicken breast. Allen et al. (1997) characterized dark chicken meat with a pH of 6.22, while light-colored meat exhibited pH values between 5.76 and 5.86.

Statistically analyzing the results, considering the calculated F-statistic value in the ANOVA table and with a significance level of 5%, the information provided by the explanatory variables is significantly better than that of a baseline average. Thus, the variable related to the type of preservation (refrigeration vs. freezing) has the highest influence on pH values (p=0.004).

The shear force recorded the highest values for the wet refrigerated sample, 23.8±2.17N, while the lowest cutting force was exhibited by the dry thawed sample (16.8±1.48N). The results obtained in this study are lower than those presented by Zhuang et al (2013), who obtained a value of 30.56 ± 7.47N for a chicken breast sample after thawing.

Statistically significant differences (p<0.0001) were observed between samples subjected to wet and dry preservation. Thus, the preservation method factor exerted significant modifications in terms of the textural indicator, shear force. The variable related to the storage type did not significantly influence the shear force of chicken breast samples (p=0.130), and the same observation was made for the interaction between the two variation factors (p=0.228).

However, the shear force was higher for both refrigerated samples compared to frozen ones, confirming literature findings that meat tenderness increases with freezing and thawing (Lagerstedt Å. et al, 2008; Leygonie C. et al, 2012a). This is due to the breakdown of muscle fibers during the thawing process, resulting from the denaturation of meat proteins, thereby reducing the shear force.

Results regarding the energy required for shearing showed a positive correlation with shear force; the higher the force required for sectioning the chicken breast sample, the greater the consumed energy. In this context, it was observed that the energy required for sectioning the thawed meat samples was lower than that needed for refrigerated samples. Following the thawing process, a lower energy requirement for meat sectioning was recorded, with a decrease of approximately 16% for samples stored in a wet environment and 3% for samples stored in a dry environment. This observation indicates a more tender or less rigid texture in the thawed meat samples.

Table 1

Influence of variability factors on physical parameters

Parameter	Refrigerated		Thawed		Significance levels of p-value		
	Wet	Dry	Wet	Dry	R/T	W/D	R/T **x** W/D
pH	6.21±0.10	6.10±0.03	6.38±0.03	6.27±0.11	0.004	0.049	0.955
Shear force (N)	23.8±2.17	18.6±1.82	20±1.58	16.8±1.48	0.130	<0.0001	0.228
Total energy (mJ)	450.2±4.44	299.8±4.21	376±3.08	291.8±2.39	0.003	<0.0001	<0.0001

R/T - storage type (R – refrigerated; T - thawed); W/D - storage method (W. - wet refrigeration / thawing; D. - dry refrigeration / thawing); ANOVA Tukey test: insignificant differences (p > 0.05); *significant differences (p < 0.05); **distinctly significant differences (p < 0.01); ***very significant differences (p < 0.001)

The loss of moisture in meat after animal slaughter is an inherent process determined by the post-mortem decrease in pH, although this loss can vary depending on various factors. In this study, the water content of chicken breast samples ranged from 76.38±0.26 (for dry thawed samples) to 76.84±0.05 (for samples refrigerated in a wet environment).

Regarding dry matter, it was found to have a higher concentration in the dry thawed samples (23.62%), which was also associated with a higher fat content. Dry matter, having an inversely proportional relationship with moisture, recorded higher values in the thawed samples compared to the refrigerated ones, regardless of the preservation method used.

Statistically, significant differences were observed between meat samples based on the type of preservation (R/T), while the preservation method (wet/dry) and the interaction between these two factors did not have a significant impact on moisture and dry matter content. Therefore, considering that the samples underwent a rapid freezing process, water losses in frozen meat samples were insignificant.

The protein content in the analyzed chicken breast samples varied between 22.02%

(for dry thawed samples) and 22.2% (for samples refrigerated in a dry environment). Lower protein content values were recorded in frozen samples, indicating some denaturation of proteins as a result of freezing, with differences being more pronounced in samples preserved in a dry environment. Fernandes et al (2016) reported a insignificant difference in protein content between frozen and refrigerated chicken breast, with average values of 18.70% and 19.50%, respectively, which were lower than the results obtained in this study.

Similar to protein content, collagen, a structural protein present in the connective tissues of meat with a significant impact on meat texture, remains relatively stable despite the freezing and thawing process of meat, experiencing no significant changes.

The lipid content of chicken breast samples ranged from 0.86% (wet refrigerated sample) to 1.52% (dry thawed sample). The obtained results are comparable to values reported in the literature for the lipid content of refrigerated chicken breast, ranging from 1.01% to 1.05% (Ali et al, 2007; Li et al, 2014), and 1.16% to 1.19% for thawed chicken breast under refrigeration after different freezing periods (Augustyńska-Prejsnar et al, 2018). Furthermore, an increase in lipid content after thawing was observed, positively correlated with the decrease in moisture content in the samples. Among the two variation factors, the type of preservation and the storage method, the type of preservation was found to be the most influential on lipid content (p<0.0001), followed by the storage method (p=0.005), with the interaction between the two being insignificant.

Table 2

Influence of variability factors on chemical components

Parameter	Refrigerated		Thawed		Significance levels of p-value		
	Wet	Dry	Wet	Dry	R/T	W/D	R/T **x** W/D
Moisture	76.84±0.05	76.62±0.13	76.4±0.16	76.38±0.26	0.0003	0.128	0.200
D.M.	23.16±0.05	23.38±0.13	23.6±0.16	23.62±0.26	0.0003	0.128	0.200
Protein	22.14±0.11	22.2±0.10	22.12±0.13	22.02±0.08	0.056	0.685	0.118
Collagen	20.52±0.08	20.48±0.13	20.46±0.11	20.38±0.08	0.107	0.219	0.675
Fat	0.86±0.05	1.06±0.11	1.4±0.16	1.52±0.08	<0.0001	0.005	0.426

R/T - storage type (R – refrigerated; T - thawed); W/D - storage method (W. - wet refrigeration / thawing; D. - dry refrigeration / thawing); ANOVA Tukey test: insignificant differences (p > 0.05); *significant differences (p < 0.05); **distinctly significant differences (p < 0.01); ***very significant differences (p < 0.001)

CONCLUSIONS

Although recognized for its practicality as a preservation method, freezing brings changes in the physico-chemical quality of meat. All evaluated chicken breast samples, whether refrigerated or frozen/thawed, exhibited average pH values indicating the development of characteristics associated with DFD (Dark, Firm, Dry) in meat, with the most significant influence coming from the type of preservation, where the frozen/thawed samples recorded the highest pH values.

Texture indicators highlighted a higher shear force in refrigerated samples compared to frozen ones. Additionally, a positive correlation was observed between shear force and the required energy, with thawed samples requiring less energy for cutting compared to refrigerated ones. These findings indicate a more tender or less rigid texture in thawed meat samples, with a significant reduction in energy requirement for cutting.

The water content of the samples did not show significant variations regardless of the storage method used. However, it was noted that dry matter had a higher concentration in thawed samples in a dry environment, thus indicating the significant influence of the preservation type (p=0.0003). Additionally, the protein content decreased in frozen samples, suggesting a possible denaturation of proteins as a result of freezing.

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