THE INFLUENCE OF PRESERVATION AND STORAGE METHOD ON QUALITY CHARACTERISTICS OF PORK: CHILLING VS. FREEZING (THAWING)

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RESEARCH ARTICLE

Abstract
The study aimed to compare the quality parameters—pH, shear force, total shear energy, and proximate chemical composition—of pork subjected to preservation procedures through refrigeration and freezing using two storage methods (wet and dry). The biological material used consisted of pork loin (m. Longissimus dorsi). Wet-stored loin samples were vacuum-packed, while dry-stored ones were directly introduced into the storage space without prior packaging. In frozen samples, a temperature measurement probe was inserted, resulting in rapid freezing of the analyzed samples. Physical and chemical analyses were conducted on refrigerated samples as they were, and frozen samples underwent slow thawing at 2-4°C. The texture of pork meat was significantly influenced by the preservation method, with freezing leading to increased tenderness, reflected in a reduction in shear force from 80N to 55.4N in wet storage and from 85.4N to 75.8N in dry storage. The nutritional quality of the frozen meat samples did not undergo major changes, with the main modifications observed in moisture content (which increased after freezing in dry storage, from 73.48% to 74.08%, and decreased in wet storage, from 75.50% to 73.64%) and fat. The protein content of pork loin samples was significantly influenced (p=0.001) by the preservation method during storage, with packaged samples recording a higher protein content (21.9% for the refrigerated sample and 21.82% for the thawed sample) compared to unpackaged ones (21.64% for the refrigerated sample and 21.4% for the thawed sample).

Keywords: pork loin (*m. Longissimus dorsi*), quality parameters, wet / dry storage, chilling or freezing meat
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INTRODUCTION

Food preservation through freezing is a widely used practice due to its ability to maintain product quality and extend shelf life. The quality of frozen food is generally closely tied to the freezing and thawing processes, as well as the freezing rate and ice crystal formation during freezing, which are crucial for minimizing tissue damage and moisture loss during thawing (Li & Sun, 2002; Kim et al, 2020; Lee et al., 2021).

Thawing represents the final stage of cooling and storage, during which the meat is returned to its pre-frozen state, with the primary goal of preserving quality attributes as close as possible to those of fresh meat. In addition to the freezing rate (which determines the quality of formed ice crystals), the thawing process is also a factor influencing the final quality of the meat (Eastridge & Bowker, 2011). Since thawing is a slower process than freezing, and foods can undergo chemical and physical deterioration during this process, becoming susceptible to microbial activity, there is a keen interest in the food industry to optimize thawing procedures (Li & Sun, 2002). Rapid thawing at low temperatures is preferred to prevent temperature rise and excessive dehydration of the food, thus maintaining its quality (Li & Sun, 2002; Eastridge & Bowker, 2011).

The quality characteristics of meat are influenced, to a greater or lesser extent, by any intervention made on the meat, regardless of its purpose for preservation. The effect of freezing and thawing processes on meat has been studied by numerous authors, with most targeting the influence of freezing temperature and the duration of meat storage in a frozen state on its qualitative properties. Gambuteanu et al (2014) studied the effect of the freezing-thawing process on the quality of the *Longissimus dorsi* muscle, stating that protein losses are related to the semi-permeability of the meat cell membrane under refrigeration conditions, especially affected during the post-mortem period, and that freezing does not have a significant contribution, regardless of the freezing rate. Savanović et al (2019) confirm that ice crystal formation during freezing causes certain physical and chemical changes after thawing, influenced by the freezing rate. The freezing rate of meat in the range of 0.23 cm/h – 1.43 cm/h significantly affects meat quality, meaning that slowly frozen samples had lower water content, lower water binding capacity, and higher weight loss after thawing, compared to rapidly frozen pork samples.

The aim of this study was to investigate the influence of low-temperature preservation (refrigeration /freezing), associated with the storage method during preservation (wet/dry), on certain physical and chemical quality characteristics of pork meat (*M. Longissimus dorsi*).

MATERIAL AND METHOD

The studied material consisted of pork loin (*m. Longissimus dorsi*) purchased in a refrigerated state. From the study material, four experimental samples were formed, two of which were further maintained at refrigeration temperature (2-4°C), while the other two underwent a freezing stage for 24 hours, followed by slow thawing under refrigeration conditions, preceding the qualitative analyses. The temperature evolution during the freezing and thawing processes was monitored by inserting a temperature recording probe into the meat sample before the freezing stage.

For each of the two preservation methods (refrigeration/freezing), two types of maturation, wet and dry, were employed. Dry maturation involved keeping the meat samples at refrigeration/freezing temperatures under the influence of humidity and air currents in the respective chambers, while wet maturation involved placing the meat samples in vacuum-sealed bags.

Thus, four pork meat samples were obtained, subjected to the following treatments:

- Sample preserved by dry refrigeration;
- Sample preserved by wet refrigeration;
- Sample preserved by dry freezing for 24 hours and dry thawing;
- Sample preserved by wet freezing for 24 hours and wet thawing.

Experiments were conducted on the refrigerated meat samples, aiming to observe differences in pH, textural indicators (shear force and total energy consumption), and proximate chemical composition.

pH values for pork meat samples were determined using a digital pH meter (HANNA HI 99163), which automatically recorded acidity values. Before measuring the acidity of 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 electrode was inserted into the meat samples at five distinct sampling zones after prior cleaning with distilled water.

Texture tests were conducted using a Mark 10 mechanical testing machine (USA) and a Mark 10 Series 7 dynamometer with a range from 0 to 1000 N and a resolution of 0.2 N. The testing probe was a V-shaped knife WERNER BRATZLER. The test involved shear-cutting at a knife travel speed of 200 mm/min, and the obtained graph was of force versus displacement type.

The maximum shear force of the cylindrical-shaped meat sample was recorded, and the mechanical work or energy required for cutting the sample was calculated. Meat samples were collected using a stainless steel cylindrical probe with a length of 6 cm, a width of 2 cm, and a diameter of 25 mm, ensuring equal-sized meat pieces.

The proximate chemical composition of the meat samples was analyzed using the automatic FoodCheck analyzer. This device operates on the principle of an infrared spectrophotometer, analyzing a meat sample based on the infrared absorption properties determined in the sample spectrum. The device's operation begins with emitting a light beam using a tungsten-halogen lamp that reaches the monochromator's light slit. The monochromator diffracts through an optical barrier into monochromatic light, which passes through the exit slit into the compartment where the meat sample is located. After passing through the sample, part of the light is collected by a detector that transmits a photometric signal, from which reference values are calculated, forming the basis for the obtained results of the parameters.

To assess the differences in quality parameters between refrigerated and thawed pork meat samples, the data were subjected to a two-way analysis of variance (preservation type – refrigeration, thawing, and maturation method – wet, dry) using the XLSTAT program (Addinsoft, 2023)."

RESULTS AND DISCUSSIONS

During the freezing process, temperature variations were monitored, thus determining the type of freezing to which the pork meat samples were subjected based on the time it took to complete freezing.

Wet freezing recorded a decrease in the meat sample temperature over a 24-hour period, from 9.2 ºC to -27.5 ºC, with a cooling rate of 0.74ºC/h, indicating that the product underwent rapid freezing (Figure 1). In the wet thawing stage, the sample temperature increased over a 24-hour period from -27.5 ºC to 2.8 ºC, averaging 0.63ºC/h (Figure 2).

In dry freezing, the sample temperature decreased over a 24-hour period from 7.3 ºC to -27.6 ºC, averaging 0.73ºC/h, indicating that the product underwent rapid freezing (Figure 1). The sample temperature during dry thawing increased over a 24-hour period from -27.6 ºC to 2.7 ºC, averaging 0.63 ºC/h (Figure 2).

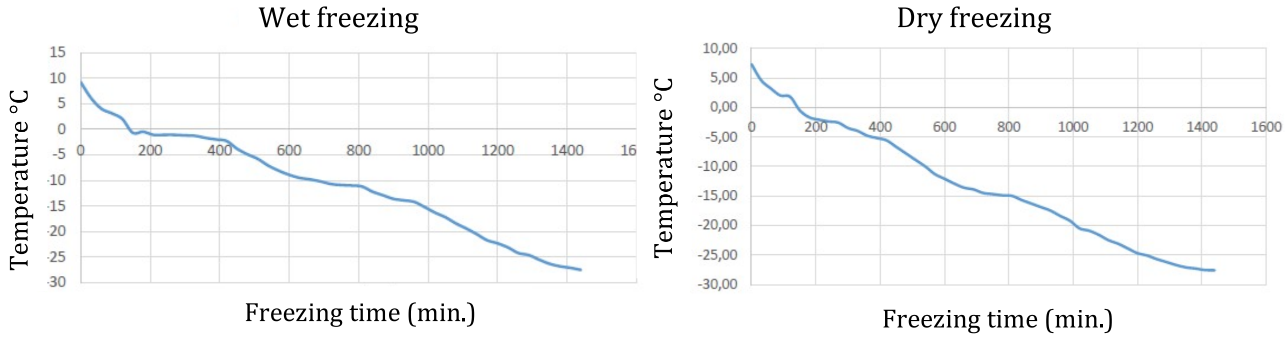

Figure 1 **Temperature graph for pork meat freezing**

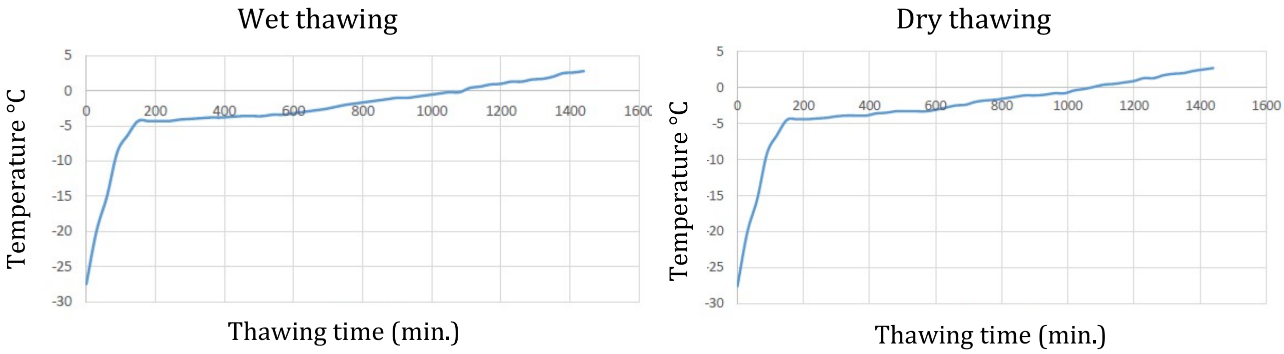

Figure 2 **Temperature graph for pork meat thawing**

Table 1 presents the results obtained for the physical parameters regarding pH, shear force, and total shear energy for the four pork meat samples subjected to wet and dry refrigeration and freezing/thawing.

After thawing, both wet-stored and dry-stored samples experienced a significant decrease in pH values (p<0.0001). The lowest pH value was observed in the wet-thawed pork loin sample (5.46), while the highest pH was recorded in the dry-refrigerated loin sample (6.15). The wet storage method led to a more pronounced pH decrease during refrigeration and freezing. The results obtained in this study align with Hwang et al (2018), who reported lower pH values for wet-aged shoulder blade and pork belly samples compared to dry aging. Another study (Ciobanu et al, 2022) demonstrates a significant influence of the aging method on the pH of different muscle regions in the pork carcass. Aksu et al (2005) explain the increase in pH during dry aging through the formation of nitrogen compounds resulting from the proteolysis process.

The textural indicators of pork loin were influenced by the storage method, with wet storage causing a decrease in shear force and total energy, both for refrigerated samples (from 85.4N to 80N) and thawed samples (from 75.8N to 55.4N). Freezing the pork loin samples also significantly affected the textural parameters (p<0.0001), with a more pronounced decrease observed in wet aging.

The increase in tenderness, defined by the reduction in shear force values after thawing, could be attributed to the breakdown of muscle fibers caused by enzymatic activity and the formation of ice crystals, which physically affect the muscle fiber structure (Vieira et al, 2009). Lee et al (2021) also reported the importance of freezing temperature on ice crystal formation and tenderness, while Lagerstedt et al (2008) linked shear force to storage conditions. In this study, despite the samples undergoing rapid freezing, the freezing process significantly influenced (p<0.0001) the textural parameters, leading to increased tenderness, especially in samples stored in a wet environment. For samples stored in a dry environment, the increase in tenderness after thawing was limited, attributed to cellular contraction and surface strengthening caused by dehydration (Drummond & Sun, 2010).

Table 1

Influence of variability factors on physical parameters

Parameter	Refrigerated		Thawed		Significance levels of p-value		
	Wet	Dry	Wet	Dry	F1	F2	F1 x F2
pH	5.64±0.10	6.15±0.15	5.46±0.11	5.80±0.09	<0.0001	<0.0001	<0.0001
Shear force (N)	80±2.55	85.4±2.41	55.4±2.19	75.8±1.92	<0.0001	<0.0001	<0.0001
Total energy (mJ)	1392±1.87	1451±1.87	835±3.67	1259±2.35	<0.0001	<0.0001	<0.0001

F1 - preservation type (refrigerated vs. thawed); F2 - storage method (wet refrigeration / thawing vs. 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 moisture content in the pork meat samples (Table 2) varied from 73.48% (dry refrigeration) to 75.5% (wet refrigeration). After thawing, a decrease in moisture content was observed in the samples stored in a wet environment. Considering that this method favors water retention in meat, the thawing process, even if done in vacuum-sealed bags, led to the loss of water due to ice crystal formation. In contrast, freezing and thawing pork in a dry environment resulted in a slight increase in moisture compared to the refrigerated sample. This outcome can be attributed to more intense water losses during storage under the influence of air currents in the refrigeration environment, as well as the release of water molecules during the thawing process following ice crystal formation.

After thawing, the average protein content in the pork meat samples ranged from 21.4% (dry thawing) to 21.82% (wet thawing), slightly lower values compared to samples preserved only by refrigeration (Table 2). In the cell fluid released during thawing, water-soluble substances, minerals, vitamins, including proteins, are lost in the freeze-thaw process, reducing the nutritional value of the product (Savanović et al, 2019). Gambuteanu et al (2014) associate the modification of protein content in thawed meat with the number and position of ice crystals formed during freezing, directly related to the freezing rate, and the fragmentation of myofibrils, a phenomenon that occurs in meat at low temperatures.

Although there were differences in protein content between refrigerated and thawed samples, statistically, this variation factor - type of preservation - did not have a significant influence (p=0.083). A higher degree of influence on protein content was represented by the storage method variation factor (p=0.001), while the interaction between these two factors had a nonsignificant influence (p=0.369).

The fat content in the pork loin samples ranged from 3.8% (wet refrigeration sample) to 4.5% (wet thawed sample). The fat content did not exhibit a precise variation pattern, with both factors and the interaction between them significantly influencing this parameter. Thus, in refrigerated samples, dry storage resulted in higher lipid content compared to vacuum-sealed samples, while freezing led to higher fat content in the vacuum-sealed pork loin sample compared to the one maintained during freezing and thawing under the influence of the environmental factors of the storage space.

Table 2

Influence of variability factors on chemical components

Parameter	Refrigerated		Thawed		Significance levels of p-value		
	Wet	Dry	Wet	Dry	F1	F2	F1 x F2
Moisture	75.50±0.22	73.48±0.35	73.64±0.21	74.08±0.08	0.001	<0.0001	<0.0001
Protein	21.9±0.16	21.64±0.28	21.82±0.19	21.4±0.10	0.083	0.001	0.369
Collagen	20.16±0.09	19.62±0.08	19.6±0.10	19.9±0.16	0.013	0.029	<0.0001
Fat	3.8±0.37	4.4±0.10	4.5±0.10	4.16±0.11	<0.0001	<0.0001	<0.0001

F1 - preservation type (refrigerated vs. thawed); F2 - storage method (wet refrigeration / thawing vs. 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

The preservation through rapid freezing of pork loin samples and slow thawing at refrigeration temperature significantly influenced the texture, causing an increase in tenderness, indicated by the decrease in shear force values. Freezing and thawing led to a more pronounced decrease in pH during storage compared to preservation through refrigeration. The nutritional quality of the meat samples subjected to freezing did not undergo major changes, with the most affected parameters being moisture and fat content. The changes in the protein content of the pork loin samples analyzed were primarily attributed to the storage method during preservation, as keeping the meat in a closed, vacuum-sealed environment resulted in better preservation of proteins during the conservation processes.

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