INFLUENCE OF REFRIGERATION, FREEZING AND DE-FREEZING METHOD ON THE CHEMICAL COMPOSITION, CALORICITY AND CERTAIN RHEOLOGICAL-TEXTURAL TRAITS OF POULTRY MEAT

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The paper brings new data on the chemical composition and energetic value of the poultry meat, under the action of freezing as well as on the way in which meat texture, analysed instrumentally, is influenced by the chosen de-freezing method. Eighty carcasses of chicken broiler of the same origin were analysed and symmetrically randomly distributed in 4 groups: REF-refrigerated meat + 3 groups of frozen meat, thawed through different methods: FDCW-cold water; FDWW-warm water; FDMW-microwaves. The chemical composition revealed increased content of water (+1.02% in breast, +0.79% in thighs) and decreased proteins levels (-2.78% in breast, -2.75% in thighs) in FDCW vs. REF, due to hydro soluble organic matters leakage during de-freezing, as well as to water uptake from the de-freezing environment. Better chemical stability was observed in thighs ($p<0.05$), and poorer in breast ($p<0.001$). Refrigerated meat was also richer in calories (+1.06%...+3.04%). Texturally, it was noticed a decrease of frozen meat firmness, compared to the refrigerated one, of: 5.37-6.25% (FDCW), 11.36-13.33% (FDWW), 8.88-9.68% (FDMW) and a similar dynamic of the Warner-Bratzler shear forces: 81.5 N (REF) to 73.5 N (FDWW) ($p<0.001$, breast) and 80.5 N (REF) to 72.70 N (FDWW) ($p<0.001$, thighs). The meat preserved through freezing and de-frozen in warm water or under microwaves flow presented the highest textural alterations leading, eventually, to a lower sensorial quality.

Key words: poultry meat, refrigeration, freezing, proteins, texture

INTRODUCTION

The ultimate quality of the meat, as well as the observance of the good practices in processing meat and its derived products is strictly related to the knowledge of the metabolic aspects of skeletal musculature in living animals as well as during post-slaughter maturation and storage periods [8]. The knowledge of the normal and abnormal physiological and microbiological phenomena occurring during meat maturation and short/longterm storage could contribute in predicting accurately the ultimate quality of a certain food, before passing through the regular processing stages [2].

Moreover, the aspects related to the modifications of meat textural and chemical features, as they are influenced by the preservation method, must be well known and managed. It is known that the most sensitive components altered throughout freezing are the lipids and their subsequent fractions [4]. Also, it is expected to experience loss of hydro soluble nutrients due to both applied freezing and thawing method [14]. The research carried on meat shear force dynamics revealed no influence of freezing upon this trait [7] or, on the contrary, certain levels of influence are given by the freezing methods, duration or meat treatment prior to freezing [10]. In this respect, the research focused on the assessment of poultry quality traits dynamics (chemical composition, energy content and textural profile elements) as influenced by its preservation method (refrigeration, freezing), or by the carcass cut belonging, knowing the treatments underwent by animal muscle after slaughter [1, 3], as well as the metabolic profile of the muscle tissues could influence the ultimate quality of the meat as foodstuff or food [9, 13].

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MATERIAL AND METHOD

Hypothesis: Preservation method of poultry meat does affect its physical, chemical, nutritional features or its textural profile.

Experimental factors:

a) *method of preservation* (applied on 80 broiler carcasses):

- refrigeration 5 days at +4ºC (REF group);
- freezing 3 months at -18 ºC and thawing in cold water (7-12 ºC) (FDCW group);
- freezing 3 months at -18 ºC and thawing in warm water (37-40 ºC) (FDWW group);
- freezing 3 months at -18 ºC and thawing in microwave oven (standard defrost program) (FDMW group).

b) *carcass part* (different as inner muscular metabolic type)*:*

- breast (white meat, mainly glycolytic metabolic type)
- thighs (red meat, mainly oxidative metabolic type).

Reasoning criterions (measured on 2 or 4 groups x 10 repetitions/trait):

a) Meat chemical composition (water, dry matter, minerals, proteins, lipids, nitrogen free extract – g/100g) (analytical standards: humidity-SR ISO 1442:1997, ashes-SR ISO 936:1998, total nitrogen-SR ISO 937:2007, lipids-SR ISO 1443:2008)

b) Meat energy content (Kcal/100 g) (calculation using the F.A.O. proximate composition transforming relation into gross energy [6]

c) Certain textural profile traits:

- firmness (Δdef^{-1mm} x10) – deformation measured objectively with a micrometre, reversed negatively and multiplied by 10, in order to achieve unitary values;
- Warner Bratzler shear force (N shear force) (in accordance with the method proposed by [15].

Statistical processing: descriptive and ANOVA algorithm, in accordance with [12].

RESULTS AND DISCUSSIONS

The analytical findings on the chemical composition and meat caloricity are presented in tables 1 (breast samples) and 2 (thighs samples).

In refrigerated breast meat, water content reached 74.43±0.34 g/100g, with very low variation (0.45%), while the total dry matter level was 25.57±0.34 g/100g. Crude ash was measured at 1.18±0.05g/100g. Out of the organic matter, total lipids reached 1.13±0.06 g/100 g, nitrogen free extract reached 0.73±0.06 g/100g while the total nitrogen matters (proteins) were measured at the 22.52±0.34 g/100g level (very good to good homogeneity=1.50…7.57%).

Table 1 Chemical composition and caloricity of refrigerated & frozen breast meat

Proximate composition (g/100 g)	**REFRIGERATED** (Mean±StDev	V%)	**FROZEN** (Mean±StDev	V%)	**ANOVA**
Dry matter	25.57±0.34	1.32	24.81±0.31	1.24	Highly significant p (0.000008) < 0.001
Water	74.43±0.34	0.45	75.19±0.09	0.41	Highly significant p (0.000008) < 0.001
Ash	1.18±0.05	4.34	1.20±0.01	2.99	Not significant p (0.343)>0.05
Total lipids	1.13±0.06	5.13	1.15±0.01	8.82	Not significant p (0.515)>0.05
Total nitrogen matters	22.52±0.34	1.50	21.91±0.15	1.79	Highly significant (0.0004) < 0.001
Nitrogen free extract	0.73±0.06	7.57	0.56±0.01	18.60	Highly significant P(0.0000003) < 0.001
Gross energy (Kcal/100g)	109.40±1.54	1.41	106.17±1.21	1.14	Highly significant p (0.00009) < 0.001

In frozen breast samples (table 1), water content reached 75.19±0.09 g/100g, while the total dry matter content was calculated at 24.81±0.31 g/100g. Hydric content was higher in those frozen and thawed samples, compared to the refrigerated ones ($p<0.001$), due to

cytoplasm exudate from the muscle tissue (cell membrane breakage due to freezing) replaced by water uptake from the thawing environment (cold water). Crude ash reached 1.20±0.01 g/100g meat. In the organic matter composition there were detected 1.15±0.01 g/100g total lipids, 0.56±0.01 g/100g nitrogen free extract and 21.91±0.15 g/100g total nitrogen matters (proteins). Variation coefficient values were higher, suggesting good toward poor or very poor homogeneity of the analysed traits, underlining therefore the main modifications of the meat during freezing and thawing (cells lysis followed by loss of certain deposited carbohydrates-glycogen from the cytosol).

Analysis of variance revealed highly significant differences ($p<0.001$) for the water, total dry matter, total nitrogen matters and nitrogen free extract levels, suggesting a probability above 99.99% that the proportion of such nutrients in poultry meat will be influenced by the preservation method (refrigeration vs. freezing & thawing).

Speaking of the caloric inner content of the breast meat, it varied between 106.17 Kcal/100 g (frozen meat) and 109.40 Kcal/100 g (refrigerated meat). Statistical analysis revealed highly significant differences ($P<0.001$), i.e. a probability closed to 100% that the gross energy in frozen breast meat would be 3% lower than in the refrigerated one (table 1).

In thighs muscles (table 2), refrigerated samples, water content varied between 71.09 and 72.45 g/100g resulting an average of 71.69±0.41 g/100g sample, while the total dry matter content varied within the 27.55 and 28.92 g/100g meat, with an average of 28.31±0.41 g/100g. Crude ash level was 0.97±0.06 g/100g. Total lipids content was higher than in breast samples, knowing the physiological predisposition for fat depositing intra-abdominal and on the medial and caudal-lateral sides of the thighs in chicken, resulting and average value of 8.51±0.04 g/100 g meat. This richer fat content provides better palatability (juiciness, crispiness, tenderness) to the lower limbs meat, compared to the breast musculature which is drier, harder and gummy, presenting less fat and more connective tissue. On the contrary, protein mean level reached 18.34±0.51 g/100g while the nitrogen free extract was calculated at 0.48±0.07 g/100g.

Table 2 Chemical composition and caloricity of refrigerated & frozen thighs meat

Proximate composition (g/100 g)	**REFRIGERATED** (Mean±StDev)	V%)	**FROZEN** (Mean±StDev)	V%)	**ANOVA**
Dry matter	28.31±0.41	1.46	27.80±0.46	1.64	Distinguished significant 0.001 < P(0.009) < 0.01
Water	71.69±0.41	0.58	72.20±0.46	0.63	Distinguished significant 0.001 < P(0.009) < 0.01
Ash	0.97±0.06	6.59	0.94±0.10	10.26	Not significant P (0.295)>0.05
Total lipids	8.51±0.13	1.58	8.59±0.21	2.48	Not significant P (0.321)>0.05
Total nitrogen matters	18.34±0.51	2.80	17.85±0.43	2.41	Significant 0.01 < P(0.021) < 0.05
Nitrogen free extract	0.48±0.07	14.10	0.42±0.06	14.85	Significant 0.01 < P(0.026) < 0.05
Gross energy (Kcal/100g)	157.08±1.76	1.12	155.43±2.87	1.85	Not significant P (0.104)>0.05

Freezing thighs meat at -18ºC, during 3 months, followed by cold water thawing induced slight modification of chemical composition compared to refrigeration (table 2). Average water content reached 72.20±0.46 g/100 g while the dry matter one was calculated at 27.80±0.46 g/100 g (lower than in refrigerated samples). Crude ash content reached 0.94±0.10 g/100g. Out of the organic matters, lipids participation reached in average 8.59±0.21 g/100g, while the total nitrogen matters average content was calculated at

17.85±0.43 g/100g. For all dry matter compounds the values in the frozen meat were below the ones detected in refrigerated meat, resulting distinguished significant differences ($p < 0.01$) for water, dry matter (more than 99.9% likelihood of modification under the influence of freezing); not significant ones in crude ash and lipids ($p > 0.05$, freezing does not affect this compounds) and significant ones for the compounds which are mostly found in thawed meat exudate (proteins and NFE, $p < 0.05$) (above 95% likelihood of proteins and nitrogen free extract loss through freezing/thawing compared to refrigeration).

Although the difference related to thighs meat caloricity was +1.06% in favour of refrigerated meat (157.08 vs. 155.43 Kcal/100g), the statistical analysis did not reveal any degree of significance (freezing does not significantly affect the thighs meat energetic content).

Concerning the textural traits and according to the measurements run on breast muscles, maximal deformations were recorded for the frozen meat and thawed in warm water (11.08±0.08 mm) and minimal ones for the refrigerated samples (9.83±0.06 mm), resulting lower firmness for the first situation (0.90±0.02), compared to the second one - microwaves (0.93±0.02); to cold water thawing (0.96±0.03), or to the refrigerated meat (1.02±0.02) (table 3).

The differences between the refrigerated and frozen/thawed meat were found between 6.25 – 13.33% (more deformation and less firmness in thawed meat).

Table 3 Firmness (Δdef^{-1mm} x10) dynamics of refrigerated & frozen chicken meat

Carcass Cut	REF (Mean±StDev | V%)		FDCW (Mean±StDev | V%)		FDWW (Mean±StDev | V%)		FDMW (Mean±StDev | V%)	
Breast	1.02±0.02	2.01	0.96±0.03	2.89	0.90±0.02	2.40	0.93±0.02	2.45
	REF vs. FDCW: Highly significant P(0.00003) < 0.001 REF vs. FDWW: Highly significant P(0.0000004) < 0.001 REF vs. FDMW: Highly significant P(0.000006) < 0.001 FDCW vs. FDWW: Highly significant P(0.0001) < 0.001 FDCW vs. FDMW: Significant (0.039) < 0.05 FDWW vs. FDMW: Distinguished significant 0.001 < P(0.008) < 0.01							
Thighs	0.98±0.02	2.19	0.93±0.02	1.90	0.88±0.02	2.79	0.90±0.02	1.89
	REF vs. FDCW: Highly significant P(0.000002) < 0.001 REF vs. FDWW: Highly significant P(0.0000008) < 0.001 REF vs. FDMW: Highly significant P(0.000001) < 0.001 FDCW vs. FDWW: Highly significant P(0.00002) < 0.001 FDCW vs. FDMW: Highly significant P(0.0004) < 0.001 FDWW vs. FDMW: Not significant P(0.054) > 0.05							

In thighs cut parts, average deformation reached 10.17±0.07 mm (refrigeration), 10.72±0.06 mm (cold water thawing), 11.12±0.07 mm (microwaves thawing), and 11.37±0.10 mm (warm water thawing). These absolute values led to recalculated firmness of 0.98 in refrigerated samples and of 0.88-0.93 in frozen samples, while the differences were -5.38% to -11.36%, compared to refrigeration (table 3, fig. 1).

Analysis of variance revealed certain levels of significance for the differences between the averages of each experimental condition (table 3). It is most likely that freezing would affect meat firmness ($p<0.001$) and the best method of thawing, in order to preserve a condition as close as possible to the fresh refrigerated meat, is thawing in cold water.

Deformation and firmness dynamics underlined better resilience of breast muscles against the structural and physical alterations during cold storage (freezing), compared to thighs ones. This could be explained through the pectorals richness in connective network, through more developed muscle cells, both on cross and longitudinal sections, traits that would allow wider volumetric modifications

of the cytoplasm aggregation states throughout different preservation methods using cold.

In order to validate these findings on the firmness, shear force was measured on samples, using a Warner-Bratzler instrument (table 4, fig. 1). In breast samples, the forces increased from 73.50±1.51 N (FDWM group), to 75.10±1.79 N (FDMW group), to 79.10±1.79 N (FDCW group) and to 81.50±0.48 N, eventually (REF group) (table 4). Less 3.03% …to 10.88% force was needed to shear the frozen and thawed breast meat, compared to the refrigerated one.

Table 4 Shear force (N) dynamics of refrigerated & frozen chicken meat

Carcass cut	REF (Mean±StDev)	V%)	FDCW (Mean±StDev)	V%)	FDWW (Mean±StDev)	V%)	FDMW (Mean±StDev)	V%)
Breast	81.50±1.51	1.85	79.10±1.79	2.27	73.50±1.51	2.05	75.10±1.79	2.39
	REF vs. FDCW: Distinguished significant 0.001 < P(0.004) < 0.01 REF vs. FDWW: Highly significant P(0.0000006) < 0.001 REF vs. FDMW: Highly significant P(0.00000008) < 0.001 FDCW vs. FDWW: Highly significant P(0.000005) < 0.001 FDCW vs. FDMW: Highly significant P(0.00009) < 0.001 FDWW vs. FDMW: Significant 0.01 < P(0.044) < 0.05							
Thighs	80.50±1.35	1.68	78.70±1.42	1.80	72.70±1.77	1.68	74.80±1.75	1.68
	REF vs. FDCW: Distinguished significant 0.001 < P(0.009) < 0.01 REF vs. FDWW: Highly significant P(0.0000001) < 0.001 REF vs. FDMW: Highly significant P(0.000000001) < 0.001 FDCW vs. FDWW: Highly significant P(0.0000001) < 0.001 FDCW vs. FDMW: Highly significant P(0.00003) < 0.01 FDWW vs. FDMW: Significant 0.01 < P(0.015) < 0.05							

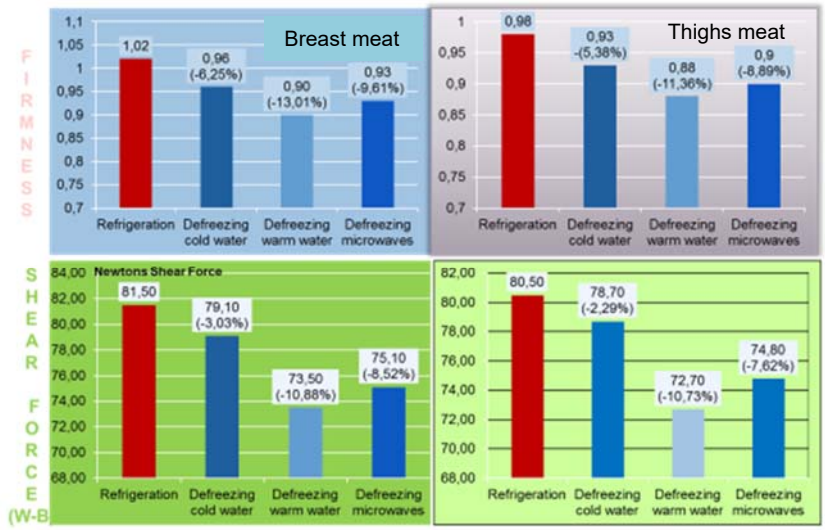

Fig. 1 Textural traits dynamics in chicken meat, as influenced by preservation method

In thighs samples, there were calculated shear force mean values of: 72.70±1.77 N (warm water thawing); 74.80±1.75 N (microwaves thawing); 78.70±1.42 N (cold water thawing); 80.50±1.35 N for refrigerated meat (table 4). Therefore, the forces needed to shear the frozen meat samples were 2.29% … 10.73% lower than those applied in the refrigerated samples, suggesting more cohesive texture in the latter ones (fig. 1). Distinguished significant differences occurred for the comparisons run

between refrigeration and freezing/thawing in cold water ($p<0.01$). Better tenderness could also occur in 95% of the situations ($p<0.05$) when freezing followed by thawing in cold water/microwaves is applied against refrigeration, as preserving method (table 4).

Although the achieved results are not doubtful, as follow up, the investigations must be continued, using a larger sampling range and of certain complementary analytical methods (analytical chemistry combined with spectroscopy NIRS or Raman; complete profile textural analysis combined with tasting experts sensory panel), or, why not, through the widening of the analytical palette (protein quality – amino acids levels and their association with the ideal protein concept [11], lipid profiling – cholesterolemy and fatty acids typology; analysis of the oxidative stress in the tissues, after preservation etc. [5].

CONCLUSIONS

Refrigeration preserved better the nutrients content in the analysed samples, in comparison with the freezing, in which especially certain amounts of hydro soluble nutrients have been lost during thawing.

In all situations, usage of freezing as preservation method vs. refrigeration resulted in slightly lower caloric meat, due to the loss of intramuscular organic chemical constituents through thawing exudative processes, regardless the method applied.

Freezing induced more intense modification of cells and tissue structure which led to loss of firmness and, consequently better tenderness (however, at texture loss costs).

When refrigeration is not an option to store fresh meat, it is recommended to freeze it and to use cold water thawing in isolated bags in order to preserve most of the nutritional content and of the original textural features.

REFERENCES

[1] Boișteanu P.C., Lazăr R., Ciobanu M.M.: The influence of the temperature and scalding time on the textural profile of chicken meat, Lucrări Științifice, Universitatea de Științe Agricole și Medicină Veterinară, Seria Zootehnie, 2015, 63:189-192.

[2] Cassens R. G., Marple D. N., Eikelenboom G.: Animal Physiology and Meat Quality. Contribution from the College of Agricultural and Life Sciences, Muscle Biology Manuscript No. 51., Advances in Food Research, 197,5 21:71-155.

[3] England E. M., Scheffler T. L., Kasten S. C., Matarneh S. K., Gerrard D. E.: Exploring the unknowns involved in the transformation of muscle to meat, Meat Science, 2013, 95(4):837-843.

[4] Erickson M.C.: Lipid Oxidation: Flavor and Nutritional Quality Deterioration, in: Erickson M.C., Hung Y.C.: Quality in Frozen Food, Boston, MA Springer U.S.A., 1997, 141-173.

[5] Falowo A. B., Fayemi P. O., Muchenje V.: Natural antioxidants against lipid-protein oxidative deterioration in meat and meat products: A review, Food Research International, 2014, 64:171-181.

[6] F.A.O.: Calculation of the energy content of foods – energy conversion factors (chapter 3), in FAO Food Nutrition Paper, Food energy – methods of analysis and conversion factors, edited by FAO, Rome, Italy, 2003, 18-56.

[7] Fernández P.P., Sanz P.D., Molina-García A.D, Otero L., Guignon B., Vaudagna S.R.: Conventional freezing plus high pressure–low temperature treatment: Physical properties, microbial quality and storage stability of beef meat, Meat Science, 2007, 77 (4):616-625.

[8] Honikel K. O.: Muscle physiology, meat quality, animal characteristics, meat tenderness, and meat processing, Fleischwirtschaft, 1994, 74 (9):1013-1015.

[9] Le Bihan-Duval E.: Genetic variability within and between breeds of poultry technological meat quality, Worlds Poultry Science Journal, 2004, 60 (3):331-340.

[10] Leygonie C., Britz T.J., Hoffman L.C.: Impact of freezing and thawing on the quality of meat: Review, Meat Science, 2012, 91 (2):93-98.

[11] Pereira P.M.D.C., Vicente A.F.D.B.: Meat nutritional composition and nutritive role in the human diet, Meat Science, 2013, 93 (3):586-592.

[12] Petrie A., Watson P.: Statistics for veterinary and animal science: John Wiley & Sons, 2013.

[13] Schreurs F. J. G.: Post-mortem changes in chicken muscle, Worlds Poultry Science Journal, 2000, 56 (4):319-346.

[14] Soyer A., Özalp B., Dalmış Ü., Bilgin V.: Effects of freezing temperature and duration of frozen storage on lipid and protein oxidation in chicken meat, Food Chemistry, 2010, 120 (4):1025-1030

[15] Young L.L., Lyon C.E.: Effect of postchill aging and sodium tripolyphosphate on moisture binding properties, color, and Warner-Bratzler shear values of chicken breast meat, Poultry Science, 1997, 76 (11):1587-1590.