INFLUENCE OF DIFFERENT TEMPERATURES APPLIED DURING REFRIGERATION AND FREEZING ON BROILER MEAT TEXTURE AND TECHNOLOGICAL FEATURES

L. Solomon[1*], P.C. Boişteanu[1], M.M. Ciobanu[1], Roxana Lazăr[1], R.M. Radu-Rusu[1]

[1]University of Agricultural Science and Veterinary Medicine of Iasi, Animal Science Faculty, Romania

Abstract

This research is a follow-up of previous original investigations on the influence of the temperature used during the cold treatment of broiler meat in the slaughterhouse on its nutritional quality. Hence it was found that total water content, dry matter and energy content was influenced by the temperature variations in scalding, chilling and storage, we tried to investigate whether the textural and technological parameters are also affected by such variation, both in refrigerated and frozen meat. Three groups of carcasses were studied for the refrigeration flow (one control - RC, two experimental - R1 and R2), varying the experimental factor, temperature, during scalding (RC=51-53°C, R1=53-54°C, R2=55-56°C), during chilling (RC=1-4°C, R1=2-3°C; R2=1-2°C), during sorting-packaging (RC below 2 °C; R1=8-10°C; R2=6-8°C), throughout storage prior to delivery to market (RC=0-2°C; R1 and R2=0-1°C). Also, for the frozen meat, three groups were set (FC, F1, F2), providing them the same graduations of the experimental factor like in the refrigerated groups, in the pre-freezing stages (scalding, chilling, sorting), while in the fast freezing moment, the temperature varied accordingly (control FC=-30…-35 °C, F1=-32…-33 °C, F2=-33…-34 °C). The biological material comprised 90 ROSS-308 broiler carcasses in refrigeration flow (30 per group) and 90 ROSS-308 broiler carcasses in freezing flow. Pectoral muscles were used from each carcass in pieces weighing 250 grams and were shaped in rectangular chops of 5 cm length x 1 cm width x 1 cm depth along the muscle fibers, to be submitted for shear force (SF) reading (N/cm^2) using a Warner-Bratzler (WB) chamber. Also, the same muscles were used to sample 100 g pieces to be submitted to drip loss (DL) via tube centrifugation and cooking loss (CL) analysis via boiling in sealed plastic bags. The analytical tests were carried on in duplicate per each sample. SF proved to increase as the temperature in scalding and sorting packaging was higher, due probably to more intense water loss and concentration of dry matter, which led to firmer meat: 22.48 N/cm^2 in CR, 22.96 N/cm^2 in R1 ($P<0.05$) and 23.11 N/cm^2 in R2 ($P<0.01$). The preservation through freezing acted as a tenderizer, probably due to connective tissue and to myocytes membranes disruptions: 22.48 N/cm^2 in CF, 22.96 N/cm^2 in F1 ($P<0.01$) and 23.11 N/cm^2 in F2 ($P<0.001$). However, it should be investigated to what extent the destruction of the connective stroma due to ice crystals really acts toward tenderizing, because losing the structure eventually lead to poor texture and lower juiciness. The technological parameters of the breast meat varied accordingly, following the shear force progression, thus the samples with higher WB values had lower DL and CL, with variations within the -2.5…-7.9% range ($P<0.001$), comparing to the ones which were more tender, in appearance. Follow up: sensorial analysis using trained panel of tasters, in comparison with the instrumental analysis of the textural profile.

Key words: poultry meat, refrigeration, freezing, shear force, drip loss, cooking loss

INTRODUCTION

Preserving poultry meat in order to provide longer shelf life and to reduce toward absence the threats represented by microbiological contamination is still a challenge in the processing industry [12, 16]. Many techniques have been tried out, some of them involving the classical cold treatments, such as refrigeration and freezing or freeze-drying [5], accompanied lately by some new technologies, such as drying [15],

*Corresponding author:
lucianvsolomon@gmail.com
The manuscript was received: 12.10.2020
Accepted for publication: 03.11.2020

super chilling [3], irradiation [1, 6], packaging under modified atmosphere [2], high pressure packaging [9], high frequency electro-magnetic field exposure [4, 22], electromagnetic induction [23], ultrasounds [14], packaging using nanomaterials [17] or nanoparticles[11]. However, for long term storage, freezing techniques are preferred by the industry due to the wide availability of technological equipment, to their reliability throughout long lasting usage and to the widely available know-how in exploiting and servicing such devices. It is known that the frost affects cell integrity structure, due to ice crystal formation[10] and could lead to loss of valuable nutrients when the meat is thawed [19]. Also, meat texture is supposed to be affected by freezing-thawing parameters, especially in terms of tenderness and juiciness [8, 20]. Under such circumstances, the original research tried to find out to what extent the different temperatures applied through certain key moments of cold preservation techniques in slaughterhouse could affect poultry meat texture (related to shear force, instrumentally measured), and some of its technological traits (drip loss, cooking loss).

MATERIAL AND METHOD

Goal: follow-up of previous original investigations on the influence of the temperature used during the cold treatment of broiler meat in the slaughterhouse on its nutritional quality.

Do the textural and technological parameters are also affected by such variation, both in refrigerated and frozen meat?

Hypothesis: variation of technical temperatures applied in chicken broiler carcasses scalding, chilling, packaging, storing, freezing does not significantly affect the meat shear force readings and drip and cooking loos.

Three groups (90 carcasses of Ross 308 broilers, aged 40 days at slaughter, randomly allotted in 30 carcasses per group)were constituted in the refrigeration flow (one control - RC, two experimental - R1 and R2).

Experimental factor: temperature

- scalding (RC=51-53^{0}C, R1=53-54^{0}C, R2=55-56^{0}C)
- during chilling (RC=1-4^{0}C, R1=2-3^{0}C; R2=1-2^{0}C)
- sorting-packaging (RC below 2^{0}C; R1=8-10^{0}C; R2=6-8^{0}C)
- storage prior to delivery to market (RC=0-2^{0}C; R1 and R2=0-1^{0}C).

Three groups (90 carcasses of Ross 308 broilers, aged 42 days at slaughter, randomly allotted in 30 carcasses per group)were constituted for the freezing flow (one control - FC, two experimental - F1 and F2).

Pre-freezing temperatures were applied similarly like in the refrigerating flow, during scalding and chilling, then the temperature as experimental factor varied during the freezing process: FC=-30…-35°C, F1=-32…-33°C, F2=-33…-34 °C.

Four months post freezing, the carcasses were thawed in refrigerator, at 1-4°C, then submitted for testing.

Pectoral muscles from each carcass, cut in pieces weighing 250 grams and shaped in rectangular chops of 5 cm length x 1 cm width x 1 cm depth along the muscle fibers, to be submitted for shear force (SF) reading (N/cm^2) using a Warner Bratzler (WB) rig mounted on a Perten Instruments TVT 6700 texture analyzer, using a working protocol recommended in other studies [23].

Also, the same muscles were used to sample 100 g pieces to be submitted to drip loss (DL) via tube centrifugation (15 min, 4000 rpm, at 4°C), in accordance with an analytical protocol adapted after a method in literature [18] and to cooking loss testing (CL) via boiling 45 min. in sealed plastic bags, using a method recommended by the scientific literature [7].

Each test comprised 2 replications, thus n=60 per group and per analyzed trait (shear force reading, drip loss, cooking loss).

Acquired data was submitted to descriptive statistics computation and to analysis of variance calculation, followed by post-hoc testing, in order to assess the significance level of the differences between means, using a GraphPad Prism 8 for Windows statistical software, in accordance with the methods proposed in literature for agricultural and food experimental data [13].

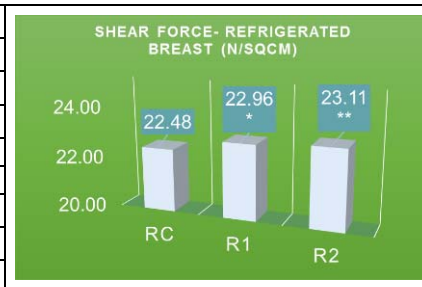
RESULTS AND DISCUSSIONS

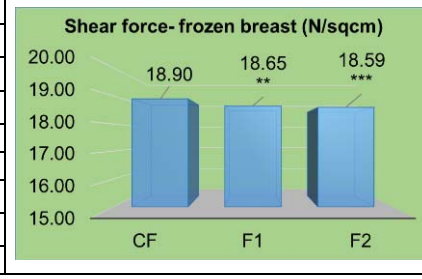
Data on the shear force reading of refrigerated and frozen-thawed fillets are presented in table 1 (chart included).

In control group of the refrigerated samples, the shear force varied between 20.8 and 25.60 N/cm^2, resulting an average of 22.48±0.15 N/cm^2, that exceeded with 2.14% (P<0.05) and with 2.80% (P<0.01) the values read for groups R1 (22.96±0.12 N/cm^2) and R2 (23.11±0.09 N/cm^2). The findings suggest that higher temperatures in scalding, corroborated with lower ones in chilling and with higher ones in packaging induced either more moisture loss, then a loss of meat juiciness and an increased forced necessary to cross-section the samples, simulating thus a less tender meat during mastication or induced sarcomere shortenings, then a higher opposition of the meat to be sectioned and chewed in real consumer eating process. This would be interesting to examine as a follow-up of the research.

Table 1 – Average values of the Shear force readings (N/cm^2) achieved on refrigerated and frozen-thawed broiler breast fillets

Refrigerated meat					
Groups	Mean	Std. error	CV %	Min.	Max.
CR	22.48	±0.15	6.26	20.80	25.60
R1	22.96	±0.12	3.61	21.80	24.10
R2	23.11	±0.09	2.30	21.80	23.70
Comparisons	%	Stat. significance			
RF	=100%	RC vs. R1	*	0.01<P=0.024<0.05	
R1	+2.14%	RC vs. R2	**	0.001<P=0.002<0.01	
R2	+2.80%	R1 vs. R2	Ns	0.05<P=0.24	
Frozen – thawed meat					
Groups	Mean	Std. error	CV %	Min.	Max.
CF	18.90	±0.09	2.83	18.10	19.70
F1	18.65	±0.07	1.80	18.10	19.30
F2	18.59	±0.07	1.78	18.20	19.20
Comparisons	%	Stat. significance			
CF	=100%	FC vs. F1	**	0.001<P=0.003<0.01	
F1	-1.32%	FC vs. F2	***	P=0.0002<0.001	
F2	-1.62%	F1 vs. F2	Ns	0.05<P=0.35	





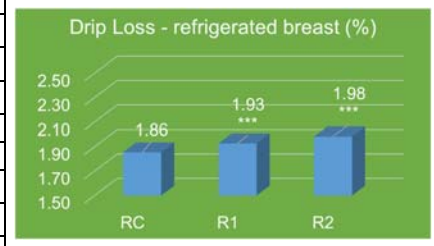
In the frozen samples, the results revealed that the lowering of the freezing temperature and its maintenance it within tighter intervals, compared to control, induced probably a more intense degradation of the muscle cells membranes and of the inner connective stroma in the meat, resulting, in appearance, a more tender meat in F1 and F2 group, less 1.3%…1.62% force being needed to cross section the samples. However, these findings should be correlated with the technological traits of the meat, because loss of structure in meat is often accompanied by drip loss. The differences between treatments were distinguished significant (FC vs. F1) and highly significant (FC vs. F2).

Drip loss values are revealed in table 2 (charts included), for both types of fillets analyzed (refrigerated and frozen-thawed). Also, the 2nd investigated technological trait, the cooking yield revealed values presented in table 3 (charts included).

Related to the drip loss percentage, in refrigerated meat, control group, this was assessed between 1.72-1.90%, resulting and average of 1.86±0.04%, value lower with 3.94-6.90% than those observed in R1 and R2 groups. The differences between experimental treatments (R1=1.93% DL, R2=1.98% DL) and the control samples were both highly significant (P<0.001), suggesting thus that higher temperatures in scalding and packaging points influence the drip loss with a probability above 99.9%.

Table 2 – Drip loss values (%)
measured on refrigerated and frozen-thawed broiler breast fillets

Refrigerated meat					
Groups	Mean	Std. error	CV %	Min.	Max.
CR	1.86	±0.04	4.14	1.72	1.97
R1	1.93	±0.03	3.47	1.80	1.99
R2	1.98	±0.03	2.66	1.91	2.09
Comparisons	%	Stat. significance			
RF	=100%	RC vs. R1	***	$P=1.77x10^{-7}<0.001$	
R1	+3.94%	RC vs. R2	***	$P=6.19x10^{-19}<0.001$	
R2	+6.90%	R1 vs. R2	***	$P=2.01x10^{-6}<0.001$	
Frozen – thawed meat					
Groups	Mean	Std. error	CV %	Min.	Max.
CF	2.76	±0.04	3.17		2.60
F1	2.83	±0.03	1.86		2.71
F2	2.94	±0.03	2.16		2.85
Comparisons	%	Stat. significance			
CF	=100%	RC vs. R1	***	$P=4.57x10^{-7}<0.001$	
F1	+2.55%	RC vs. R2	***	$P=5.01x10^{-23}<0.001$	
F2	+6.24%	R1 vs. R2	***	$P=1.82x10^{-16}<0.001$	



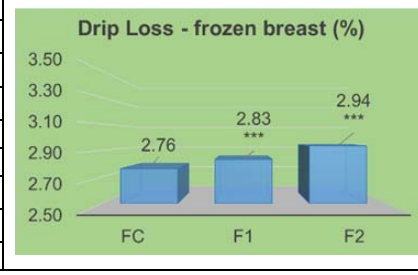
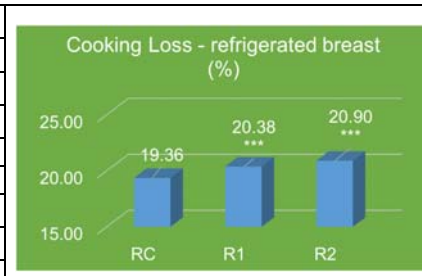
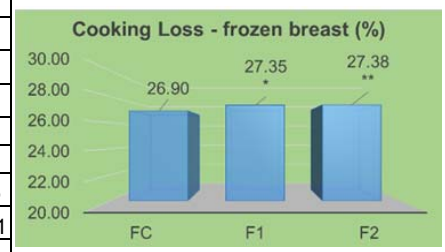


Table 3 – Cooking loss values (%)
measured on refrigerated and frozen-thawed broiler breast fillets

Refrigerated meat					
Groups	Mean	Std. error	CV %	Min.	Max.
CR	19.36	±0.08	1.99	18.70	19.90
R1	20.38	±0.08	1.94	19.80	20.90
R2	20.90	±0.09	2.21	20.10	21.90
Comparisons	%	Stat. significance			
RF	=100%	RC vs. R1	***	$P=1.6x10^{-27}<0.001$	
R1	+5.27%	RC vs. R2	***	$P=2.4x10^{-39}<0.001$	
R2	+7.95%	R1 vs. R2	***	$P=1.1x10^{-9}<0.001$	
Frozen – thawed meat					
Groups	Mean	Std. error	CV %	Min.	Max.
CF	26.90	±0.13	3.55	25.60	28.30
F1	27.35	±0.13	3.68	25.70	28.90
F2	27.38	±0.10	2.26	26.80	28.40
Comparisons	%	Stat. significance			
CF	=100%	RC vs. R1	*	$0.01<P=0.013<0.05$	
F1	+1.67%	RC vs. R2	**	$0.001<P=0.002<0.01$	
F2	+1.77%	R1 vs. R2	n.s.	$0.05<P=0.64$	





In frozen samples (table 2), drip loss was even higher (2.76% in FC, 2.83% in F1 and 2.94% in F2) ($P<0.001$ for all comparisons), following the same trend like in shear force, suggesting also the more severe damage in muscle structure due to a more intense forming of ice crystals at lower freezing temperatures.

Cooking loss (table 3) varied accordingly, thus it reached 19.36% in refrigerated control samples and was 5.27% higher in R1 group (CL=20.38%) and 7.95% more intense in R2

group (CL=20.90%), compared to control, the differences being highly significant (P<0.001).

In frozen samples of breast fillets, the cooking loss was more intense comparing to refrigeration and reached 26.90% in control group, while the experimental treatments were 1.67% and 1.77% higher in terms of cooking loss (F1=27.35% CL, P<0.05 vs. control and F2=27.38% CL, P<0.01 vs. control). Lower significance values of the differences between treatments in frozen samples suggests the fact that freezing affects meat structure in a closer manner, regardless the temperatures used in freezing, if we discuss the phenomenon in comparison with the refrigeration.

As follow-up, the instrumental and analytical findings on meat texture subjected to different cold treatment temperatures should be accompanied by a sensory evaluation panel and/or by a histological study on muscle structure, to identify to which extent the frost destroys the connective stroma and the sarcolemma in muscle fibers.

CONCLUSIONS

Shear Force proved to increase as the temperature in scalding and sorting packaging was higher, due probably to more intense water loss and concentration of dry matter.

The preservation through freezing acted as a tenderizer, probably due to connective tissue and to myocytes membranes disruptions.

It should be investigated to what extent the destruction of the connective stroma due to ice crystals really acts toward tenderizing, because losing the structure eventually lead to poor texture and lower juiciness.

The technological parameters of the breast meat varied accordingly, following the shear force progression, thus the samples with higher Shear Force values had lower Drip Loss and Cooking Loss values.

REFERENCES

[1] Ahn D.U., Kim I.S., Lee E.J.: Irradiation and additive combinations on the pathogen reduction and quality of poultry meat. Poultry Science, 2013, 92(2), 534-545.

[2] Arvanitoyannis I.S., Stratakos A.C.: Application of modified atmosphere packaging and active/smart technologies to red meat and poultry: a review. Food and Bioprocess Technology, 2012, 5(5), 1423-1446.

[3] Banerjee R., Maheswarappa N.B.: Superchilling of muscle foods: Potential alternative for chilling and freezing. Critical reviews in food science and nutrition, 2019, 59(8), 1256-1263.

[4] Bhatt K., Vaidya D., Kaushal M., Gupta A., Soni P., Arya P., Sharma C.: Microwaves and Radiowaves: In Food Processing and Preservation. Int. J. Curr. Microbiol, 2020, App. Sci, 9(9), 118-131.

[5] Ciurzyńska A., Lenart A.: Freeze-drying-application in food processing and biotechnology-a review, 2011, Polish Journal of Food and Nutrition Sciences, 61(3), 165-171.

[6] Joshua Ajibola O.: An overview of irradiation as a food preservation technique, 2020, Novel Research in Microbiology Journal, 4(3), 779-789.

[7] Küçüközet A.O., Uslu M.K.: Cooking loss, tenderness, and sensory evaluation of chicken meat roasted after wrapping with edible films, 2018, Food Science and Technology International, 24(7), 576-584.

[8] Lee Y.S., Saha A., Xiong R., Owens C.M., Meullenet J.F.: Changes in broiler breast fillet tenderness, water-holding capacity, and color attributes during long-term frozen storage, 2008, Journal of Food Science, 73(4), E162-E168.

[9] Lerasle M., Federighi M., Simonin H., Anthoine V., Rezé S., Chéret R., Guillou S.: Combined use of modified atmosphere packaging and high pressure to extend the shelf-life of raw poultry sausage, 2014, Innovative Food Science & Emerging Technologies, 23, 54-60.

[10] Li D., Zhu Z., Sun D.W.: Effects of freezing on cell structure of fresh cellular food materials: A review, 2018, Trends in Food Science & Technology, 75, 46-55.

[11] Mohana N.C., Mithun P.R., Rao H.Y., Mahendra C., Satish S.: Nanoparticle applications in sustainable agriculture, poultry, and food: trends and perspective, 2020, In Nanotoxicity (pp. 341-353). Elsevier.

[12] Newell D.G., Koopmans M., Verhoef L., Duizer E., Aidara-Kane A., Sprong H., van der Giessen J.: Food-borne diseases—the challenges of 20 years ago still persist while new ones continue to emerge, 2010, International journal of food microbiology, 139, S3-S15.

[13] Pagano M., Gauvreau K.: Principles of biostatistics, CRC Press, 2018.

[14] Piñon M.I., Alarcon-Rojo A.D., Renteria A.L., Carrillo-Lopez L.M.: Microbiological properties of poultry breast meat treated with high-

intensity ultrasound, 2020, Ultrasonics, 102, 105680.
[15] Rahman M.S.: Dried food properties: Challenges ahead, 2005, Drying Technology, 23(4), 695-715.
[16] Shimoni E., Labuza T.P.: Modeling pathogen growth in meat products: future challenges, 2000, Trends in food science & technology, 11(11), 394-402.
[17] Souza V.G.L., Rodrigues C., Valente S., Pimenta C., Pires J.R.A., Alves M.M., Fernando A.L.: Eco-friendly ZnO/Chitosan bionanocomposites films for packaging of Fresh Poultry Meat, 2020, Coatings, 10(2), 110.
[18] Traore S., Aubry L., Gatellier P., Przybylski W., Jaworska D., Kajak-Siemaszko K., Santé-Lhoutellier V.: Higher drip loss is associated with protein oxidation, 2012, Meat science, 90(4), 917-924.
[19] Vorobiev E., Lebovka N: Cooling, Freezing, Thawing and Crystallization, 2020, In Processing of Foods and Biomass Feedstocks by Pulsed Electric Energy (pp. 179-207). Springer, Cham.
[20] Wang B., Li F., Pan N., Kong B., Xia X.: Effect of ice structuring protein on the quality of quick-frozen patties subjected to multiple freeze-thaw cycles, 2020, Meat Science, 108335.
[21] Zand N., Foroudi F., Mailova E., Voskanyan V.A.: Sterilization of flexible pouch by high frequency electromagnetic induction, using cooked chick and chick meal, 2010, African Journal of Microbiology Research, 4(19), 2011-2021.
[22] Zhang J., Bowker B., Yang Y., Pang B., Zhuang H.: Effects of deboning time and thawing method interaction on sensory descriptive profiles of cooked chicken breast and thigh meat, 2020, LWT, 120, 108939.
[23] Zhuang H., Savage E.M.: Variation and Pearson correlation coefficients of Warner-Bratzler shear force measurements within broiler breast fillets, 2009, Poultry science, 88(1), 214-220.