THE EFFECT OF FROZEN STORAGE ON THE QUALITY OF VACUUM-PACKAGED TURKEY MEAT

Katarzyna Śmiecińska[1], Natalia Hnatyk[1], Tomasz Daszkiewicz[1], Dorota Kubiak[1], Paulius Matusevičius[2]

[1]Department of Commodity Science and Animal Raw Material Processing,
University of Warmia and Mazury in Olsztyn
Oczapowskiego 5, 10-719 Olsztyn, Poland; e-mail: katarzyna.smiecinska@uwm.edu.pl
[2]Department of Animal Nutrition, Lithuanian University of Health Sciences
Tilžes 18, LT-47181, Kaunas

Abstract. The objective of this study was to determine changes in the chemical composition, physicochemical and organoleptic properties, and lipid oxidation rate of breast muscles (*musculus pectoralis*) of male heavy-type BIG–6 turkeys. Vacuum-packaged meat samples were stored in the freezer for two and six weeks.

Freezer storage of vacuum-packaged turkey meat had no significant effect on weight loss which, however, tended to increase throughout storage. A significant increase in the content of total protein ($p \leq 0.05$) and soluble protein ($p \leq 0.01$) was noted in meat stored for six weeks. The concentrations of other chemical compounds (dry matter, fat, minerals and non-protein nitrogen) were similar in all groups. Frozen meat stored for two and six weeks had a higher contribution of redness (a^*) in comparison with meat evaluated after chilling (control group). A significantly lower contribution of yellowness (b^*) and lower drip loss were noted in meat stored for six weeks. No significant increase in lipid oxidation rates (TBARS values) or significant changes in the eating quality of meat were observed. The shear force of frozen meat stored for two weeks decreased significantly relative to the control group.

Keywords: turkey meat, meat quality, chemical composition, physicochemical and sensory properties, freezer storage, vacuum packaging.

Introduction. The share of turkey production in the poultry sector has increased rapidly in recent years. The world turkey population has also increased in response to the growing demand for poultry meat (Fraqueza and Barreto 2009). The nutritional and health benefits of turkey meat include low cholesterol levels, high amounts of niacin (vitamin PP), riboflavin (vitamin B2), minerals and lysine (essential amino acids). Poultry meat is also highly valued by consumers for its high eating quality (Kijowski 1996).

The key criteria for evaluating overall meat quality are sensory quality, nutritional value and processing suitability that is affected by physicochemical properties. Numerous studies investigating post-mortem changes in muscle tissue have indicated that meat quality is a complex trait determined by a variety of interrelated factors such as genotype, nutritional regime, slaughter method, carcass chilling method, the conditions and time of storage (Binke 2004). Meat spoils quickly and easily, and it needs to be properly preserved. Meat susceptibility to spoilage results from its chemical composition, mostly a high content of water, protein, carbohydrates and fat that undergoes oxidation and rancidification, which leads to undesirable changes in the sensory properties and nutritional value of meat. The nature of those changes is determined by raw material, processing technology and preservation method (Branscheid et al. 2004, Guidi et al. 2006, Huff-Lonergan and Lonergan 2005).

Freezing is a preservation method that allows to maintain high quality of meat and extend its shelf-life. Freezing and freezer storage are good ways to preserve surplus meat. Excess meat production is also exported frozen worldwide (Leygonie et al. 2012).

The quality of frozen meat is determined mostly by the quality of raw material, the parameters of freezing (primarily the rate of freezing) and thawing, and storage conditions. Thus, the final quality of frozen meat is affected by both primary and secondary changes that occur at successive stages of the freezing and storage processes. Spoilage of frozen meat and deterioration of its quality may result from the interactions between different factors such as post-slaughter carcass handling, microbial contamination, activities of tissue enzymes and bacterial enzymes, and the time, temperature and method of storage (Jacky et al. 2011, Leygonie et al. 2012, Vieira et al. 2009, Zhou et al. 2010).

The objective of this study was to determine changes in the quality parameters of vacuum-packaged turkey meat stored in the freezer for two and six weeks.

Material and methods. The experimental material comprised 30 male heavy-type BIG–6 turkeys raised to 20 weeks of age in a deep litter floor system, in pens, under controlled microclimatic conditions. The birds were fed complete diets in pellet form in a five-phase feeding program. During one-hour transport to the abattoir, the turkeys were placed in cages and loaded on a truck. They were slaughtered on arrival, on an automated slaughter line. The average live body weight of turkeys before slaughter was approximately 20 kg. The pH_1 of breast muscles (*musculus pectoralis*) was measured around 15 minutes *post mortem*. The carcasses were immersion- and air-chilled. Approximately 24 hours *post mortem*, the pH of breast muscles was measured again (pH_{24}).

Samples of breast muscles (*musculus pectoralis*), without skin and subcutaneous fat, were collected from chilled carcasses during dissection, and were transported to the analytical laboratory in isothermal containers with ice. Three samples of similar weight (approx. 500 g) were

collected from each muscle. Samples intended for freezing were weighed, vacuum-packaged in polyethylene bags, frozen in a blast freezing tunnel at air temperature of around -28˚C, and stored at that temperature. After two and six weeks of freezer storage, meat samples were air-thawed at 2˚C until the temperature measured at the geometric center of the sample reached 4˚C.

Quality parameters were evaluated on chilled breast muscles before storage, approximately 24 hours post mortem (30 samples) – group I (control), and after two weeks (30 samples) – group II and six weeks of freezer storage (30 samples) – group III.

The analysis of the proximate chemical composition of meat included the determination of dry matter content, total protein, soluble protein and non-protein nitrogen content by the Kjeldahl method, ash content, fat content by the Soxhlet method (AOAC 1990). pH_u (ultimate) was measured in the water homogenates of meat ago (control group) and after two and six weeks of freezer storage, and the water-holding capacity of meat was determined by the Grau and Hamm method (Van Oeckel et al. 1999). Meat color was determined based on the values of CIELAB coordinates, *L** (lightness), *a** (redness) and *b** (yellowness) (CIE 1978). The rate of lipid oxidation was measured based on the TBARS value (Pikul et al. 1989) that was expressed as mg malondialdehyde per kg meat. Absorbance was measured using a Specord 40 spectrophotometer (Analytic Jena AG). Shear force of meat was determined using a Warner-Bratzler head (500 N) attached to an Instron universal testing machine (model 5542). Prior to a sensory evaluation, meat was cooked in a 0.6% NaCl solution until the temperature measured at the geometric center of the sample reached 80°C (Baryłko-Pikielna et al., 1964). The sensory properties of cooked meat were evaluated on a five-point scale (1 point – the lowest score, 5 points – the highest score) by five trained panelists (PN-ISO 4121: 1998). Meat weight loss after freezer storage was determined by subtracting the final weight of a sample (after two-week and six-week storage) from its initial weight, and was expressed as a percentage of the initial weight.

The data were processed statistically by one-way ANOVA using the STATISTICA ver. 9.0 data analysis software system (StatSoft Inc. 2009). Least squares mean (LSM) and standard deviations (SD) were calculated. The significance of differences between means in groups was estimated by Duncan's test.

Results and discussion. Freezing is the most widely used, non-destructive, highly effective and cost-efficient method of food preservation. The freezing process significantly extends the storage life of food products. Another advantage of freezing is the fact that it causes the smallest changes in the nutritional value of meat, in comparison with other preservation methods.

Table 1 shows meat weight loss during freezer storage and the proximate chemical composition of breast muscles. Freezing leads to weight loss that results from natural processes such as evaporation and drip loss (Leygonie et al. 2012). As the water freezes the concentration of the remaining solutes (protein, carbohydrates, lipids, vitamins and minerals) increases, thereby disrupting the homeostasis of the complex meat system (Lawrie 1998).

Table 1. **Weight loss and the proximate chemical composition of turkey breast muscles** (*musculus pectoralis)*

Specification	Statistical measures	Control group chilled muscles (Group I)	Time of freezer storage, weeks		Statistical significance of differences
			2 (Group II)	6 (Group III)	
Weight loss (%)	LSM	-	4.43	5.84	-
	SD	-	1.88	1.49	
Dry matter (%)	LSM	26.05	26.35	26.54	-
	SD	0.85	0.55	0.34	
Fat (%)	LSM	1.24	1.22	1.05	-
	SD	0.66	0.39	0.36	
Ash (%)	LSM	1.10	1.14	1.14	-
	SD	0.04	0.03	0.01	
Total protein (%)	LSM	24.50	24.12	24.81	II<III*
	SD	0.75	0.51	0.59	
Soluble protein (%)	LSM	6.97	6.61	7.21	II<III**
	SD	0.37	0.39	0.38	
Non-protein nitrogen (%)	LSM	0.56	0.63	0.59	-
	SD	0.03	0.02	0.01	
Values in the same row followed by different letters are significantly different: *P≤0.05; **P≤0.01					

Weight loss values affect changes in the chemical composition and properties of thawed meat. Meat weight loss tended to increase during freezer storage, but no statistically significant differences in average weight loss were noted between groups.

Analysis of the proximate chemical composition of meat revealed that freezing had no destructive effect on the quality attributes that determine the nutritional value of meat. The average concentrations of dry matter, fat, mineral compounds in ash form and non-protein nitrogen

were comparable in all groups. A significant increase in the content of total protein and soluble protein was noted in meat during freezer storage. Denaturation of protein contained in frozen meat is limited because freezing inhibits biochemical and microbiological processes involved in the breakdown of meat components. Freezer storage may increase the gelling capacity of muscle proteins, in comparison with fresh meat immediately after slaughter when rigor mortis sets in, which is an important consideration when assessing the processing suitability of meat. This is related to greater solubility of muscle proteins in frozen meat (Farouk et al. 2003). The above correlation was also observed in the present study. It should be noted, however, that the soluble protein content of meat increased significantly only after six weeks of freezer storage. Freezer storage and thawing extend the activity of endogenous proteolytic enzymes that are responsible for muscle protein degradation and loosening of muscle tissue structure (Farouk et al. 2003). Chan et al. (2011) also reported an increase in the soluble protein content of vacuum-packaged frozen meat stored for three weeks at -30ºC and thawed at 4ºC.

The ultimate quality of meat, in particular its physicochemical properties, are determined by physical, chemical, biochemical and microbiological changes that occur during freezing and thawing. Table 2 presents the physicochemical properties of meat before and after freezer storage.

The pH value, which reflects the rate of post mortem glycolysis, is a key indicator of meat quality. In turkey breast muscles, which are mostly composed of white muscle fibers, post mortem glycolysis may be accompanied by rapid anaerobic carbohydrate degradation. A significant decrease in the pH of turkey breast muscles, observed after slaughter, is associated with deterioration of meat technological quality, and it may affect the water-holding capacity, texture and color lightness of meat (Sośnicki et al. 1998, Hahn et al., 2001, Galobart and Moran 2004, Werner 2009). In our study, the average values of pH_1, pH_{24} and pH_u determined in the breast muscles of control group turkeys pointed to the high quality of the analyzed meat. Freezer storage had no significant effect on pH_u values measured in the water homogenates of thawed meat.

Color is one of the most important properties of meat that affect the consumers' decision to buy a given product (Brewer et al. 2002). Based on a visual evaluation of this trait, consumers form opinions about the freshness and eating quality of meat (Mancini and Hunt 2005). The rate and extent of changes in meat color are determined by oxygen access. Those changes become more intense with extended frozen storage that contributes to meat surface dehydration and oxygen penetration into the muscle. Changes in meat color are only partially reversible upon thawing, and therefore they are considered highly undesirable (Leygonie et al. 2012). Such changes can be easily prevented by protecting meat surface against drying and oxygen access, which is possible under adequate storage conditions (Leygonie et al. 2011).

Table 2. **Physicochemical properties and TBARS values of turkey meat before and after freezer storage**

Specification	Statistical measures	Control group chilled muscles (Group I)	Time of freezer storage, weeks		Statistical significance of differences
			2 (Group II)	6 (Group III)	
pH_1	LSM	5.65	5.68	5.99	-
	SD	0.51	0.53	0.34	
pH_{24}	LSM	5.69	5.72	5.73	-
	SD	0.05	0.52	0.12	
pH_u (ultimate pH)	LSM	5.87	5.85	5.89	-
	SD	0.14	0.06	0.18	
L (lightness)*	LSM	55.49	55.18	56.71	-
	SD	2.58	2.57	0.77	
a (redness)*	LSM	7.70	9.94	9.11	I<II**; III*
	SD	1.39	1.43	0.86	
b (yellowness)*	LSM	11.79	11.71	7.73	I, II>III**
	SD	2.86	1.43	2.02	
TBARS value (mg malondialdehyde/kg meat)	LSM	0.29	0.32	0.38	-
	SD	0.09	0.11	0.15	
Water-holding capacity (cm^2) Grau and Hamm method	LSM	4.59	4.67	3.48	I, II>III**
	SD	0.54	0.85	0.72	
Cooking loss (%)	LSM	24.53	24.29	23.03	-
	SD	2.67	1.73	1.70	
Drip loss (%)	LSM	1.18	1.71	0.96	-
	SD	0.83	0.93	0.35	
Values in the same row followed by different letters are significantly different: * P≤0.05; ** P≤0.01					

An analysis of the values of CIELAB coordinates did not reveal significant differences in average color lightness *L** between groups. Freezer storage affected the percentages of red (*a**) and yellow (*b**) hues in turkey meat. Frozen meat stored for two and six weeks had a significantly higher contribution of redness (*a**) in comparison with control meat samples. A highly significantly higher contribution of yellowness (*b**) was noted in control meat samples and in meat stored for two weeks, compared with meat stored for six weeks.

Freezer storage does not inhibit the activity of lipases that break down fat. The compounds produced during the oxidative degradation of lipids are the primary cause of deterioration in meat quality during storage, including undesirable changes in color (parameters *L*a*b**) and sensory properties (Nam et al. 2001, Gök 2008). In the current study, freezer storage had no significant effect on TBARS values (Table 2), pointing to minor changes resulting from lipid oxidation, adequate storage conditions and the protective function of vacuum packaging. Oxygen present in the packaging has been shown to exert prooxidative effects (John et al. 2005, Mitsumoto et al. 2005, Gök 2008, McMillin 2008).

Water-holding capacity is yet another factor that affects the technological quality of meat (Oeckel van et al. 1999). Water-holding capacity determines meat weight loss during storage and the meat's ability to retain water during heat treatment (Aaslyng et al. 2003). Drip loss during thawing is a synthetic indicator of the overall quality of the frozen product. Under standard conditions, drip loss during thawing may reflect the degree of muscle tissue damage during freezing, and support a comparison between different freezing methods (Sobina 1998). Drip loss is associated with the loss of numerous valuable nutrients. To better describe the ability of meat to hold its own water, the values of forced drip loss, cooking loss and natural drip loss were determined in the study.

Highly statistically significant differences in forced drip loss were noted between groups. Meat samples evaluated after chilling (control group) and stored for two weeks (group II) were characterized by highly significantly greater drip loss than meat samples stored for six weeks (group III). Differences between groups in cooking loss and natural drip loss were not statistically significant. A correlation was also found between drip loss and meat weight loss. Greater water loss during freezer storage inhibits drip loss, which could point to greater water-holding capacity of meat stored for longer periods. Such a relationship was also observed by other authors (Chwastowska and Kondratowicz 2005, Leygonie 2012).

Table 3 shows the sensory properties and shear force values of turkey meat before and after freezer storage. The eating quality of meat that had been frozen properly and stored under adequate should not deteriorate significantly.

Table 3. **Sensory properties (points) and shear force values of turkey meat before and after freezer storage**

Specification	Statistical measures	Control group chilled muscles (Group I)	Time of freezer storage, weeks		Statistical significance of differences
			2 (Group II)	6 (Group III)	
Aroma (intensity)	LSM	4.69	4.50	4.34	-
	SD	0.37	0.38	0.42	
Aroma (desirability)	LSM	4.69	4.50	4.44	-
	SD	0.37	0.38	0.42	
Taste (intensity)	LSM	4.19	4.31	3.87	-
	SD	0.65	0.53	0.58	
Taste (desirability)	LSM	4.19	4.31	3.87	-
	SD	0.65	0.53	0.58	
Juiciness	LSM	3.81	3.75	3.44	-
	SD	0.88	0.65	0.68	
Tenderness	LSM	3.94	4.25	3.75	-
	SD	0.86	0.71	0.84	
Shear force (N)	LSM	21.21	15.77	18.94	I>II*
	SD	6.18	3.29	5.17	
Values in the same row followed by different letters are significantly different: * P≤0.05					

The sensory attributes of meat were evaluated on a five-point scale. Control group muscles received the highest scores for aroma intensity and desirability, which were found to decrease insignificantly throughout freezer storage. Frozen meat stored for two weeks scored highest for taste intensity and desirability. Turkey breast muscles stored for six weeks were characterized by a slightly less desirable and intense taste, compared with samples from the remaining groups. Juiciness decreased with prolonged storage, and meat evaluated after two weeks of freezer storage was characterized by the highest tenderness. However, the changes in the sensory properties of turkey meat noted in our study were not statistically significant. The absence of significant differences in the sensory attributes of turkey breast muscles indicates that the parameters of meat freezing, thawing and storage were properly selected.

The shear force values of meat corresponded with the

results of tenderness assessment. Two-week freezer storage contributed to a significant ($p \leq 0.05$) decrease in the shear force values of turkey breast muscles in comparison with control samples. A positive effect of freezer storage under adequate conditions on meat tenderness has been reported by numerous authors (Shanks et al. 2002, Farouk et al. 2003, Lagerstedt et al. 2008). However, temperature fluctuations during storage may lead to undesirable changes in the frozen product, resulting from ice recrystallization. Ice recrystallization is the major cause of quality deterioration in frozen meat, including undesirable changes in texture, tenderness, color and water-holding capacity (McMillin 2008).

Conclusions

1. Freezer storage of vacuum-packaged turkey meat had no significant effect on weight loss which, however, tended to increase throughout storage.

2. A significant increase in the content of total protein ($p \leq 0.05$) and soluble protein ($p \leq 0.01$) was noted in meat stored for six weeks. The concentrations of other chemical compounds (dry matter, fat, minerals and non-protein nitrogen) were similar in all groups.

3. Freezer storage significantly affected the functional properties of meat. Frozen meat stored for two and six weeks had a higher contribution of redness (a^*) in comparison with meat evaluated after chilling (control group). A significantly lower contribution of yellowness (b^*) and lower drip loss were noted in meat stored for six weeks.

4. No significant increase in lipid oxidation rates (TBARS values) was observed, which could be indicative of adequate freezing, freezer storage and thawing conditions as well as the protective function of vacuum packaging.

5. Freezer storage and thawing had no significant effect on the sensory quality of turkey meat. The shear force of frozen meat stored for two weeks decreased significantly relative to the control group. A tendency towards better tenderness and the decrease in the shear force of frozen meat seem to confirm the hypothesis that freezer storage has a beneficial influence on meat tenderness.

References

1. Aaslyng M. D., Bejerholm C., Ertbjerg P., Bertram H. C., Andersen H. J. Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. Food Quality Preference. 2003. 14(4). P. 277–288.

2. AOAC. Official Methods of Analysis, 15th Ed. Assoc. of Official Analytical Chemists, Washington, D.C. 1990.

3. Baryłko-Pikielna N., Kossakowska T., Baldwin Z. The selection of optima method to prepare beef and pork for the sensory evaluation. Roczniki Instytutu Przemysłu Mięsnego. 1964. 1. P. 111–132.

4. Binke R. Vom muskel zum fleisch. Fleischwirtschaft. 2004. 5. P. 224–227.

5. Branscheid W., Hahn G., Wicke M. Qualitet von Putenfleisch. Fleischwirtschaft. 2004. 11. P. 109–112.

6. Brewer M. S., Jensen J., Prestat C., Zhu L. G., McKeith F. K. Visual acceptability and consumer purchase intent of pumped pork loin roats. Journal Muscle Foods. 2002. 13(1). P. 53–68.

7. CIE. Recommendations on uniform color spaces-color difference equations. Psychometric Color Terms. Supplement No. 2 to CIE Publication No. 15 (E-1.3.1.), 1971/(TC-1-3), Commission Internationale de l'E Â clairage. Paris. 1978.

8. Chan J. T. Y, Omana D. A., Betti M. Effect of ultimate pH and freezing on the biochemical properties of proteins in turkey breast meat. Food Chemistry. 2011. 127. P. 109–117.

9. Chwastowska I., Kondratowicz J. Właściwości technologiczne mięsa wieprzowego w zależności od czasu zamrażalniczego przechowywania i metody rozmrażania. Żywność (Nauka, Technologia, Jakość). 2005. 3(4) Suppl. P. 11–20.

10. Farouk M. M., Wieliczko K. J., Merts I. Ultra-fast freezing and low storage temperatures are not necessary to maintain the functional properties of manufacturing beef. Meat Science. 2003. 66. P. 171–179.

11. Fraqueza M. J., Barreto A. S. The effect on turkey meat shelf life of modified-atmosphere packaging with an argon mixture. Poultry Science. 2009. 88. P. 1991–1998.

12. Galobart J., Moran E. T Jr. Freeze-Thaw and cooking effects on broiler breast fillets with extreme initial L* values. Poultry Science. 2004. 83. P. 2093–2097.

13. Gök V., Obuz E., Akkaya L. Effect of packaging method and storage time on the chemical, microbiological, and sensory properties of Turkish pastirma – A dry cured beef product. Meat Science. 2008. 80. P. 335–344.

14. Guidi A., Castigliego L., Benini O., Armani A., Iannone G., Gialfandoni D. Biochemical survey on episodic localized darkening in turkey deboned thigh meat packaged I modified atmosphere. Poultry Science. 2006. 85. P. 787–793.

15. Hahn G., Malenica M., Muller W. D., Taubert E., Petrak T. Turkey breast meat – Glycolysis post-mortem and technological properties. Fleischwirtschaft. 2001. 81. P. 120–122.

16. Huff-Lonergan E., Lonergan S. M. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science. 2005. 71. P. 194–204.

17. Jacky T. Y., Omana Ch. D. A., betti m. Effect of ultimate pH and freezing on the biochemical properties of proteins in turkey breast meat. Food Chemistry. 2011. 127. P. 109–117.

18. John L., Cornforth D., Carpenter Ch. E., Sørheim O., Pettee B. C., Whittier D. R. Color and thiobarbituric

acid values of cooked top sirloin steaks packaged in modified atmospheres of 80 % oxygen, or 0.4% carbon monoxide, or vacuum. Meat Science. 2005. 69. P. 441–449.

19. Kijowski J. Zagadnienia surowcowe, technologiczne i marketingowe w przetwórstwie mięsa drobiowego. Gospodarka mięsna. 1996. 48(12). P. 30–34.

20. Lagerstedt A., Enfalt L., Johansson L., Lundström K. Effect of freezing on sensory quality, shear force and water loss in beef *M. longissimus dorsi*. Meat Science. 2008. 80. P. 457–461.

21. Lawrie R. A. In Anonymous (Ed.), Lawrie's meat science (6th ed.) Lancaster P. A: Technomic Publishing Inc. P. 1–336.

22. Leygonie C., Britz T. J., Hoffman L. C. Oxidative stability of previously frozen ostrich *M. iliofibularis* packaged under different modified atmospheric conditions. International Journal of Food Science and Technology. 2011. 46. P. 1171–1178.

23. Leygonie C., Britz T. J., Hoffman L. C. Impact of freezing and thawing on the quality of meat: review. Meat Science. 2012. 91. P. 93–98.

24. Mancini R. A., Hunt M. C. Current research in meat color. Meat Science. 2005. 71. P. 100–121.

25. McMillin K. W. Where is MAP going? A review and future potential of modified atmospheric packaging for meat. Meat Science. 2008. 80. P. 43–63.

26. Mitsumoto M., O'Grady M. N., Kerry J. P., Buckley D. J. Addition of tea catechins and vitamin c on sensory evaluation, colour and lipid stability during chilled storage in cooked or raw beef and chicken patties. Meat Science. 2005. 69. P. 773–779.

27. Nam K. C., Hur S. J., Ismail H., Ahn D. U. Lipid oxidation, volatiles, and color changes in irradiated raw turkey breast during frozen storage. Journal of Food Science. 2001. 67(6). P. 2061–2066.

28. Pikul J., Leszczyński D. E., Kummerow F. A. Evaluation of three modified TBA methods for measuring lipid oxidation in chicken meat. Journal Agriculture Food Chemistry. 1989. 37(3). P. 1309–1313.

29. Polish Standard PN-ISO 4121. Sensory analysis. Methodology. Evaluation of food products by methods using five point scales. 1998. P. 9–11.

30. Shanks B. C., Wulf D. M., Maddock R. J. Technical note: The effect of freezing on Warner-Bratzler shear force values of beef *longissimus* steks across several *post mortem* aging periods. Journal of Animal Science. 2002. 80. P. 2122–2125.

31. Sobina I. Badania zmian jakości mięsa wieprzowego normalnego i wadliwego (PSE i DFD) w procesie autolizy w zależności od temperatury składowania. Rozprawy i monografie 1. Wydawnictwo ART. Olsztyn. 1998.

32. Sośnicki A., Greaser M., Pietrzak M., Pospiech E., Sante V. PSE-like syndrome in breast muscle of domestic turkeys: a review. Journal of Muscle Food. 1998. 9. P. 13–23.

33. StatSoft, Inc. Statistica (data analysis software system). Version 9.0. Tulsa, OK, USA. 2009.

34. Van Oeckel M. J., Warnants N., Boucqueé C. V. Comparison of different methods for measuring water holding capacity and juiciness of pork versus on-line screening methods. Meat Science. 1999. 4. P. 313–320.

35. Vieira C., Diaz M. T., Martinez B., Garcia-Cachan M. D. Effect of frozen storage conditions (temperature and length of storage) on microbiological and sensory quality of rustic crossbred beef at different states of ageing. Meat Science. 2009. 83. P. 398–404.

36. Werner C., Janisch S., Kuembet U., Wicke M. Comparative study of the quality of broiler and turkey meat. British Poultry Science. 2009. 50(3). P. 318-324.

37. Zhou G. H., Xu X. L., Liu Y. Preservation technologies for fresh meat – A review. Meat Science. 2010. 86. P. 119–128.

Received 2 June 2014
Accepted 23 October 2014