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Effects of different variants of pre-slaughter transport on body weight loss and meat quality in broiler chickens*)

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Summary

The aim of this study was to determine the effect of different variants of pre-slaughter procedures in the winter on body weight loss in broiler chickens, and on the proximate chemical composition and physico-chemical properties of meat. At the completion of a six-week rearing period, 240 ROSS 308 chickens were subjected to the following variants of pre-slaughter transport: no transport (N-T), transport to a distance of 100 km (T-100), 200 km (T-200) and 300 km (T-300).

The acidity of breast muscles (pH_{15} and pH_{24}) was measured with a portable meat pH-meter, HI 99163 (Hanna Instruments, Germany) supplied with an FC 232D electrode. Meat color (15 minutes and 24 hours post mortem) was determined with the use of a Minolta CR-400 chroma meter (Japan), in the CIE L* a* b* system. Water-holding capacity (24 hours post mortem) was determined as drip loss. The content of water, protein and fat in meat was determined using an InfraLab 710 near-infrared analyzer (NDC Infrared Engineering, UK).

The results of the conducted study showed that the elongation of transport length for a distance of 200 km and 300 km influenced the increase of broiler weight loss. Significantly higher (P = 0.01) weight loss was observed after transport to a distance of 200 and 300 km, compared to a group of chickens from group T-100 (respectively 2.65%, 2.36% and 1.41%).

It cannot be stated clearly that variants of transportation have contributed to the deterioration of the quality of the meat acquired. The longest transport distance resulted in a faster rate of the pectoral muscle glycolysis in group T-300 (0.69 units) compared to the other groups (0.60-0.62 units). The broiler meat from group T-300, as compared to the other groups, was also characterized by a significantly higher surface of drip loss and the parameters L * 24 and b * 24, which reflected in its significantly lighter color and lower water-holding capacity. However, the final pH values were similar in all groups and did not show any meat defects. In addition, the basic chemical composition of chicken muscles showed their good nutritional value.

Keywords: broilers, pre-slaughter transport, body weight loss, meat quality

Preventing weight loss and quality deterioration of poultry raw material remains a topical issue. Numerous studies show that the quality of meat and meat products is affected by a variety of factors, such as the genetic potential of broiler lines (1, 2, 7), sex (1, 5, 7, 23), production system (18), and pre-slaughter stress (4, 8, 15, 24, 25). Transport, including its duration, distance, conditions (12) and season of the year (9), is also a major stressor.

Broiler chickens have to be transported over long distances because EU approved slaughterhouses are often located far away from poultry houses. This is an

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important consideration, since transportation stress cannot be eliminated completely in poultry production. Therefore, efforts should be made to increase awareness of the consequences of pre-slaughter treatment, including transport, for meat quantity and quality.

The objective of this study was to determine the effect of different distances of pre-slaughter transport in the winter on body weight loss in broiler chickens, and on the chemical composition and physicochemical properties of meat.

Material and methods

The experimental materials comprised 360 unsexed ROSS 308 broiler chickens reared for six weeks in a controlled environment, in the winter season. At the completion of rearing, 240 chickens were subjected to various distance of pre-slaughter transport: no transport (N-T), transport to a distance of 100 km (T-100), 200 km (T-200) and 300 km (T-300). The chickens were divided into four groups, each of 60 birds (30 males and 30 females).

Identical management conditions were provided to all groups. Broilers were fasted from 9.00 p.m. on the day preceding slaughter, with free access to water. At 7.00 a.m. on slaughter day, the chickens were weighed and randomly allocated to groups based on the applied pre-slaughter handling procedure. The birds were transported in perforated containers adapted for use in poultry processing plants, with the dimensions of 30 × 60 × 90 cm. The number of birds per container conformed to the Council Regulation (EC) 1/2005 of 22 December 2004 on the protection of animals during transport and related operations (OJ L 3, 5.01.2005, pp. 1-44). The broilers that had not been transported prior to slaughter were sacrificed starting from 8.00 a.m. The other birds were transported to the abattoir between 8.00 a.m. and 1.00 p.m., in a vehicle adapted for poultry transportation, traveling at an average speed of 60-70 km per hour. The chickens were slaughtered in accordance with the relevant regulations. The experiment was approved by the Local Ethics Committee (Resolution No. 77/2008 of 29 October 2008).

Body weight loss was determined based on weighing before and after transport. After carcass chilling, meat acidity and color were measured on the right breast muscles, 15 minutes and 24 hours post mortem. Samples were also collected to determine the water-holding capacity and proximate chemical composition of meat.

Meat acidity was measured with a portable meat pH-meter, HI 99163 (Hanna Instruments, Germany) supplied with an FC 232D electrode. Meat color was determined with the use of a Minolta CR-400 chroma meter (Japan), based on light reflectance values in the CIE L* a* b* system, at illuminant D65 and observer angle 2^0 (14). Water-holding capacity was determined as drip loss, by the method proposed by Grau and Hamm, modified by Pohja and Niinivaara (16). Before determining the proximate chemical composition of meat, samples were thoroughly homogenized with a Buchi B-400 mixer (BUCHI, Switzerland), and then the content of water, protein and fat was determined using an InfraLab 710 near-infrared analyzer (NDC Infrared Engineering, UK).

The data were verified statistically by one-way ANOVA in an orthogonal design. Arithmetic means and standard deviations were calculated, and the significance of differences between the mean values at every level of experimental factors was determined by Duncan's test. Computations were performed using Statistica 9.0 PL software.

Results and discussion

The highest body weight loss (Tab. 1) was noted in birds transported over a distance of 200 km and 300 km. It reached 2.65% and 2.36%, respectively, and was higher ($P \leq 0.01$) than in group T-100 (1.41%). The above values remain within the reference ranges reported by other authors (5, 20, 22, 23). According to Wójcik (23), body weight loss increases with an increase in the distance traveled, from 1.1% to 4.5%, yet the total weight loss in transported broilers should not exceed 3% as it could considerably decrease carcass weight (10). In the present study, body weight loss did not exceed 3% even in birds transported to 200 km and 300 km, which indicates that appropriate pre-slaughter handling contributes to minimizing live weight losses during transportation.

The protein content of meat was affected by variants of pre-slaughter transport (Tab. 2), reaching 23.52% in group N-T, compared with 23.41% in group T-100. An increase in the protein content of meat was observed in chickens transported over a greater distance (groups T-200 and T-300). The difference between groups T-100 and T-300 was statistically significant ($P \leq 0.05$). Other authors (19, 23) also observed a significant

Tab. 1. Body weight of broiler chickens and body weight loss during variants of transport ($\bar{x} \pm SD$)

Body weight	Variants of transport			
	N-T	T-100	T-200	T-300
Body weight before transport (kg)	2.96 ± 0.29	3.10 ± 0.47	3.08 ± 0.36	3.04 ± 0.34
Body weight after transport (kg)	–	2.92 ± 0.28	3.02 ± 0.47	3.01 ± 0.35
Body weight loss (kg)	–	0.04^A ± 0.02	0.08^B ± 0.03	0.07^B ± 0.04
Body weight loss (%)	–	1.41^A ± 0.66	2.65^B ± 1.03	2.36^B ± 1.16

Explanations: A, B – $p \leq 0.01$

Tab. 2. Chemical composition of breast muscles of broiler chicken in relation to variants of transport ($\bar{x} \pm SD$)

Components	Variants of transport			
	N-T	T-100	T-200	T-300
Protein (%)	23.52 ± 0.75	23.41^a ± 0.69	23.66 ± 0.59	23.79^b ± 0.47
Fat (%)	1.82 ± 0.48	1.86 ± 0.43	1.91 ± 0.38	1.99 ± 0.41
Water (%)	73.66 ± 0.75	73.51 ± 0.56	73.49 ± 0.45	73.41 ± 0.65

Explanations: a, b – $p \leq 0.05$

increase in the protein content of chicken meat, subject to the transport distance. The percentage content of protein in broiler breast muscles may vary from 18.40% (20) to 26.99% (11), but in most cases it remains within the 21%-24% range (6, 7). The protein content of chicken meat is mostly determined by the origin of birds (1, 6, 7), yet the current results as well as the findings of Wójcik (23) and Pomianowski et al. (19) point to the impact of pre-slaughter handling.

Distance of pre-slaughter transport had no significant effect on the percentage content of water and fat in meat. A tendency towards a gradual decrease in water content and an increase in fat content was noted in transported groups, as compared with the N-T group. A significant decrease in the water content of chicken meat in response to an increase in the distance traveled in the summer was reported by Pomianowski et al. (19). Similarly as in the present study, the cited authors and Wójcik (23) observed an insignificant increase in fat concentrations in meat from broilers transported over longer distances. The proximate chemical composition of broiler muscles determined in this study is comparable with that described by other authors (7, 19, 23) and indicative of a high nutritional value of meat.

Variants of pre-slaughter transport did not lead to significant differences in meat acidity measured 15 minutes and 24 hours post mortem (Tab. 3). A comparison of pH_{15} and pH_{24} values in all groups revealed certain differences in the rate of glycolysis – acidity decreased by 0.69 units in group T-300, compared with 0.62, 0.60 and 0.62 units in groups N-T, T-100 and T-200, respectively. The differences in the rate of glycolysis were also reflected in the values of water-holding capacity (Tab. 3). Drip loss was significantly ($P \leq 0.01$) greater in group T-300, in comparison with groups N-T, T-100 and T-200.

The values of CIELAB coordinates (L*, a*, b*) are presented in Tab. 4. Measurements performed 15 minutes post mortem did not show a significant effect of distance of pre-slaughter transport on color parameters L * and a*, whereas significant differences were noted with respect to yellowness (b*) values, which were lowest in groups N-T and T-300, and highest in group T-100. After 24 hours, meat from broilers of all groups was characterized by higher color lightness, and significant ($P \leq 0.05$) differences were noted between groups T-200 and T-300. Higher L* values were observed in groups N-T and T-300 (53.87 and 54.12, respectively), compared with group T-200 (51.45). The values of yellowness differed significantly between groups – the lowest contribution of the yellow component was noted in group T-200, and the highest in group T-300 (0.14 and 0.91, respectively). Redness values were comparable in all groups.

High pH values of breast muscles in broiler chickens transported over a distance of 100 km and 200 km and in birds that were not transported prior to slaughter were noted by Wójcik (23) in the summer season, but – similarly as in the current study – pre-slaughter management had no significant effect on pH levels. Other authors (24) reported lower pH values of breast muscles in broilers subjected to different pre-slaughter handling procedures. In birds that were not transported prior to slaughter and in broilers transported to a distance of 100, 200 and 300 km, the pH_{15} of breast muscles ranged from 5.85 to 5.89, with no significant differences between groups. After 24 hours, significantly ($P \leq 0.01$) lower pH levels were found in chickens that were not transported to the abattoir. Lower ultimate pH values of the breast muscles of chickens that were not transported, compared with those transported for one to four hours, were also reported by Warriss et al. (21).

The results of water-holding capacity tests were different than those reported by other authors. Wójcik (23) found no significant differences in the water-holding capacity of meat from chickens that were not transported prior to slaughter and birds transported over a distance of 100 km and 200 km. Another study conducted in the summer (24) revealed significantly lower water-holding capacity in a group of broilers transported to a distance of 300 km, compared with groups transported to 100 km and 200 km. The opposite trend was noted in our study, which was carried out in the winter season (Tab. 3).

The current results do not support the findings of other authors (2, 3, 24) regarding the color of breast muscles. In a study by Wójcik et al.

Tab. 3. Muscle acidity and water-holding capacity of breast muscles of broiler chicken in relation to variants of transport ($\bar{x} \pm SD$)

Parameters	Variants of transport			
	N-T	T-100	T-200	T-300
pH_{15}	6.62 ± 0.15	6.61 ± 0.19	6.64 ± 0.11	6.64 ± 0.14
pH_{24}	6.00 ± 0.06	6.01 ± 0.14	6.02 ± 0.16	5.95 ± 0.08
WHC (cm^2)	4.77^A ± 0.93	4.53^A ± 0.92	4.48^A ± 0.83	5.74^B ± 1.20

Explanations: as in tab. 1.

Tab. 4. Color parameters of broiler chicken breast muscle in relation to variants of transport ($\bar{x} \pm SD$)

Parameters	Variants of transport			
	N-T	T-100	T-200	T-300
L *15	48.00 ± 2.99	46.93 ± 3.28	47.93 ± 2.35	47.12 ± 1.65
a *15	3.34 ± 0.75	3.69 ± 1.09	3.22 ± 0.78	3.32 ± 0.55
b *15	0.75^A ± 1.48	1.72^{Ba} ± 1.01	1.26 ± 0.84	1.01^b ± 0.75
L *24	53.87 ± 3.56	53.69 ± 4.58	51.45^a ± 4.16	54.12^b ± 3.69
a *24	1.49 ± 0.75	1.86 ± 1.06	1.95 ± 0.86	1.46 ± 0.80
b *24	0.33 ± 1.04	0.54 ± 0.97	0.14^a ± 1.08	0.91^b ± 1.02

Explanations: as in tab. 1 and 2.

(24), the color of the breast muscles of broilers transported in the summer to a distance of 300 km was significantly ($P \leq 0.01$) darker, compared with groups T-100 and N-T. In the present experiment, performed in the winter, the meat of chickens transported over a distance of 300 km was characterized by significantly higher lightness, in comparison with the remaining groups (Tab. 4). Bianchi et al. (2) observed no significant differences in the values of L* and b* in broilers transported over the following distances: < 40 km, 40-210 km and > 210 km, and significantly ($P \leq 0.05$) higher a* values in birds transported to < 40 km. Debut et al. (3) did not find significant differences in the color of meat from transported chickens.

According to the classification of meat quality defects based on pH_1 values (13), the occurrence of DFD meat could be expected in all groups. However, the measurements of pH, water-holding capacity and color performed 24 hours post mortem did not suggest that meat quality was affected by distance of pre-slaughter transport. As demonstrated by Debut et al. (3) and Michalczuk et al. (11), the glycolysis process in chickens is usually completed at 5.7-5.9, and the values noted in the present study were similar or insignificantly higher (5.95-6.02).

The values of color parameter L *24 (Tab. 4), which according to Langer et al. (9) should range from 44.0 to 53.0 in meat of normal quality, remained within this range or slightly exceeded its upper limit.

The findings of the current study are consistent with those of Doktor and Połtowicz (5), who analyzed the physicochemical properties of meat from broiler chickens that were not transported prior to slaughter and birds subjected to a 4-hour pre-slaughter handling procedure which included 2.5-hour transport. The cited authors noted pH_{15} 6.36 and pH_{24} 6.09 in group N-T (a decrease by 0.27 units), and pH_{15} 6.15 and pH_{24} 6.14 in transported broilers (a decrease by 0.01 units). There were no significant differences between groups with regard to the color and water-holding capacity of meat. The breast muscles of transported chickens tended to have lower L* values (a lower contribution of the red component and a higher contribution of the yellow component) and higher water-holding capacity.

Conclusions

The results of this study showed that the elongation of transport time to the slaughterhouse for a distance of 200 km and 300 km significantly influenced the increase of broiler weight loss. It cannot be stated clearly that variants of transportation have contributed to the deterioration of the quality of the meat acquired. Although the longest distance of transport resulted in a faster rate of the pectoral muscle glycolysis in this group of broiler chickens, which was reflected in its significantly lighter color and lower water absorption assessed after 24 hours, the final pH value was nevertheless similar in all groups and did not indicate the occurrence of the meat defects. In addition, the basic chemical composition of chicken muscles showed their good nutritional value.

References

1. *Baéza E., Chartrin P., Meteau K., Bordeau T., Juin H., Le Bihan-Duval E., Lessire M., Berri C.*: Effect of sex and genotype on carcase composition and nutritional characteristics of chicken meat. Br. Poult. Sci. 2010, 51, 344-353.
2. *Bianchi M., Petracci M., Cavani C.*: The influence of genotype, market live weight, transportation, and holding conditions prior to slaughter on broiler breast meat color. Poultry Sci. 2006, 85, 123-128.
3. *Debut M., Berri C., Baéza E., Sellier N., Arnould C., Guemene D., Jehl N., Boutten B., Jego Y., Beaumont C., Le Bihan-Duval E.*: Variation of chicken technological meat quality in relation to genotype and preslaughter stress condition. Poultry Sci. 2003, 82, 1829-1838.
4. *Delezie E., Swennen Q., Buyse J., Decuypere E.*: The effect of feed whitdrawel and crating density in transit on metabolism and meat quality of broilers at slaughter weight. Poultry Sci. 2007, 87, 1414-1423.
5. *Doktor J., Połtowicz K.*: Effect of transport to the slaughterhouse on stress indicators and meat quality of broiler chickens. Ann. Anim. Sci. 2009, 9, 307-317.
6. *Gornowicz E., Dziadek K.*: Zmienność składu chemicznego mięśni piersiowych i udowych w zależności od pochodzenia. Rocz. Nauk. Zoot. 2001, 28, 89-100.
7. *Gornowicz E., Pietrzak M.*: Wpływ pochodzenia kurcząt brojlerów na cechy rzeźne i jakość mięśni piersiowych. Rocz. Inst. Przem. Męs. Tłuszcz 2008, 46, 95-104.
8. *Jakubowska M.*: Kształtowanie się cech jakościowych mięsa oraz wybranych wskaźników krwi kurcząt brojlerów w zależności od ich wieku oraz dostępu do paszy i wody przed ubojem. Praca hab., Wydział Biotechnologii i Hodowli Zwierząt, ZUT, Szczecin 2010.
9. *Langer R. O. S., Simőes G. L., Soares A. L., Oba A., Rossa A., Shimokomaki M., Ida E. I.*: Broiler transportation conditions in a brazilian commercial line and occurrence of breast PSE (Pale, Soft, Exudative) meat and DFD-like (Dark, Firm, Dry) meat. Braz. Arch. Biol. Technol. 2010, 53, 1161-1167.
10. *Mazanowski A.*: Czynniki wpływające na efektywność odchowu kurcząt brojlerów, cz. IV. Pol. Drob. 1997, 5, 2-4.
11. *Michalczuk M., Niemiec J., Pietrzak D., Mroczek J.*: Wpływ różnych stymulatorów wzrostu na skład chemiczny i właściwości fizykochemiczne mięsa brojlerów. Zesz. Nauk. Prz. Hod. 2004, 72, 193-199.
12. *Mitchell M. A., Kettlewell P. J.*: Welfare of poultry during transport – a review. Proc. 8th Poultry Welfare Symposium, Cervia, Italy 18-22 May 2009, 90-100.
13. *Niewiarowicz A., Pikul J.*: pH-Wert der Hautoberfläche vor der Schlachtung als Indicator für PSE- und DFD-Fleisch bei Broilern. Fleischwirtschaft 1979, 59, 405-407.
14. *Petracci M., Baéza E.*: Harmonization of metodolgies for the assessment of poultry meat quality features. World Poultry Sci. J. 2011, 66, 137-151.
15. *Petracci M., Bianchi M., Cavani C.*: Pre-slaughter handling factors influencing poultry product quality. World Poultry Sci. J. 2010, 66, 17-26.
16. *Pohja N., Niinivaraa F. P.*: Die Bestimmung der Wasserbindung des Fleischesmittels der Konstantdrückmethode. Fleischwirtschaft 1957, 9, 193-195.
17. *Polak M.*: Wartość rzeźna kurcząt brojlerów różniących się pochodzeniem, wiekiem uboju oraz płcią. Zesz. Nauk. Prz. Hod. 2004, 72, 119-127.
18. *Połtowicz K.*: Wpływ systemu chowu na jakość mięsa drobiowego. Pol. Drob. 2006, 4, 34-40.
19. *Pomianowski J., Wójcik A., Sowińska J., Mituniewicz T., Witkowska D., Chorąży Ł., Kwiatkowska-Stenzel A.*: Wartość odżywcza mięsa kurcząt brojlerów transportowanych na różne odległości. Inż. Ap. Chem. 2011, 50, 67-68.
20. *Słowiński M., Król G.*: Wpływ odległości fermy od zakładu ubojowego i czasu oczekiwania na ubój na właściwości technologiczne mięsa kurcząt. Mięso i Wędliny 1999, 30-34.
21. *Warris P. D., Knowles T. G., Brown S. N., Edwards J. E., Kettlewell P. J., Mitchell M. A., Baxter C. A.*: Effects of lairage time on body temperature and glycogen reserves of broiler chickens held in transport modules. Vet. Rec. 1999, 145, 218-222.
22. *Warriss P. D., Pagazaurtundua A., Brown S. N.*: Relationship between maximum daily temperature and mortality of broiler chickens during transport and lairage. Br. Poult. Sci. 2005, 46, 647-651.
23. *Wójcik A.*: Wpływ podawania kurczętom brojlerom chromu lub ziół na ograniczenie niekorzystnych skutków obrotu przedubojowego. Rozpr. i Monogr., UWM Olsztyn 2007, 125, 1-110.
24. *Wójcik A., Pomianowski J., Sowińska J., Mituniewicz T., Witkowska D., Chorąży Ł., Piotrowska J.*: Wpływ obrotu przedubojowego kurcząt brojlerów na jakość technologiczną mięsa. Inż. Ap. Chem. 2011, 50, 85-86.
25. *Wójcik A., Sowińska J., Mituniewicz T., Witkowska D., Pomianowski J. F., Mielcarek S., Murawska D.*: Wpływ podawania kurczętom brojlerom fito-preparatu przed obrotem przedubojowym na właściwości fizyko-chemiczne mięsa. Zesz. Nauk. UP Wroc., Biol. Hod. Zwierz. 2011, 63, 347-354.

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