meat technology
Founder and publisher: Institute of Meat Hygiene and Technology, Belgrade

UDK: 636.5.083.312.5
ID: 254361356

Original scientific paper

Determination of weight loss and temperature of broiler carcasses during air cooling with intermittent water spraying – case study

Mladen Raseta[1], Ivana Brankovic-Lazic[1], Boris Mrdovic[1], Zolt Beckei[2]

A b s t r a c t: The aim of this study was to determine the broiler carcasses weight loss and temperature during air cooling with intermittent water spraying (3.1 m sec^{-1}, −1.5°C, 120 min) in order to optimize the poultry chilling process. Weight and temperature of broiler carcasses were measured before and after cooling. Measurements were made once a week (during six weeks) on randomly selected broiler carcasses (eight carcasses per week) on the slaughterline. The most common broiler hybrids on the domestic market were used in the study (Ross-308, Cobb 500), of different ages (34 to 41 days old), which had been transported 70 to 260 km to the slaughterhouse. In broilers originating from flocks with higher average bird live body weight (2.2 to 2.4 kg), which were held longer (41 days), slight weight losses of carcasses occurred (0.32 to 0.76%) after cooling. On the other hand, broilers which were held 34–38 days with smaller average bird live weight (1.58 to 2.1 kg) produced slight increases in carcass weights after cooling (0 to 2.18%). Temperatures of the broiler carcasses before cooling ranged from 33.00 to 41.37°C and after cooling were from 1.58 to 5.46°C. The achieved temperature of broiler carcasses depended on carcass size, and was adequate (0 to 4°C) for broilers weighing less than 2.13 kg, but carcasses of larger birds did not meet temperature regulations. The transport length influenced weight loss of live broilers, but did not affect the weight loss of broiler carcasses after cooling. Also no differences were observed in accordance to the broiler hybrid type used (Ross-308, Cobb 500).

Keywords: *broiler carcasses, air cooling, water spraying, weight loss, meat temperature.*

Introduction

In poultry processing, chilling is a crucial step that can prevent microbial growth to a level that will maximize both product safety and shelf life (*Wang and Sun,* 2003; *Carroll and Alvarado*, 2008). Also, it improves carcass appearance, but the prime purpose of chilling is to limit the growth of both pathogenic and food spoilage microorganisms (*James et al.,* 2006). In order to control pathogens in broiler processing, enhanced insight into contamination dynamics can be provided with mathematical calculation of cooling processes (*McCarthy et al*., 2017). The most significant broiler meat pathogen is *Salmonella* spp., which is one of the main causes of zoonotic diseases triggered by ingestion of contaminated meat or eggs (*Pajic et al*., 2015), followed by *Campylobacter* spp. (especially *Campylobacter jejuni*) on broiler carcasses, a worldwide problem (*Ivanovic et al*., 2008).

The most common methods for chilling poultry include water immersion or cold-air blast chilling with or without an intermittent water spray (*Mead et al.,* 2000). Air chilling is also used to chill raw poultry carcasses and parts (*Anonymous*, 2014). In Europe, the usage of air chilling to cool poultry carcasses is very common, and there are restrictions on the usage of immersion chilling (*Young and Smith*, 2004). For air chilling as opposed to immersion chilling, cross-contamination can be lower because carcasses are hung individually on the line, depending on the presence of water spray incorporated in the air chill system (*Fluckey et al*., 2003). Spraying carcasses during air chilling, which is not allowed in the European Union, can cause aerosols with bacteria to spread from carcass to carcass due to the fans blowing in air-chilled systems (*Mead et al*., 2000).

In immersion chilling, carcasses are moved through tanks containing chilled water or a mixture of ice and water (*James et al*. 2006). In the case of broilers undergoing immersion chilling, the immersion chilling process should meet hygiene criteria as specified by the competent authority and

[1]*Institute of Meat Hygiene and Technology, Kacanskog 13, 11000 Belgrade, Republic of Serbia;*
[2]*University of Belgrade, Faculty of Veterinary Medicine, Bulevar Oslobodjenja 18, Belgrade 11000, Republic of Serbia.*

Corresponding author: Mladen Raseta, *mladen.raseta@inmes.rs*

the reduction in carcass temperature should be as rapid as possible (*Anonymous*, 2005). Immersion chilling is a relatively low cost and fast chilling technique, largely employed in the South and North American poultry industries (*Rodrigues et al*., 2014). This system is used a lot in the United States of America and Brazil, two of the biggest poultry producers in the world (*Cariofi and Laurindo*, 2007). During immersion, carcasses uptake water into the intercellular spaces created during the rigor mortis (*Dufour and Renou*, 2002). If broiler carcasses are immersion cooled, the maximum amount of water absorbed into the carcasses and the base parts of the carcass must not exceed 5%, according to domestic legislation (*Anonymous*, 1988). The cooling rate is influenced by the size, shape, and fat of the carcass, as well as by the temperature and flow pattern (and stirring level) of water inside the tanks. In air chillers, the cooling rate depends on the air relative humidity and flow conditions (*Savell et al.,* 2005).

The temperature of chilled broiler meat should be between 0°C to 4°C, as stated in domestic legislation (*Anonymous*, 2014a), and only then it can be released to market (*Anonymous*, 1988). The carcass of slaughtered poultry, the edible parts and internal organs should be cooled so that the deep muscle tissue of the carcass is up to 4°C, while edible parts and organs must be up to 3°C (*Anonymous*, 2010). The FSIS Compliance Guide recommended that all poultry slaughtered and eviscerated in official establishments are chilled immediately after processing so that the internal temperature of broiler carcasses and major portions weighing under 1.8 kg are reduced to 4.4°C or below within 4 hours of processing, and carcasses weighing 1.8 to 3.6 kg within 6 hours of processing. Once chilled, poultry needs to be packaged and shipped at 4.4°C or less (*Anonymous*, 2014).

During transportation from the farm to the slaughterhouse, broilers are exposed to various stressful factors that influence post-mortem muscle metabolism and consequently meat quality (*Babic et al*., 2014). Transport is an entirely new environment to which the animal has not been adapted, and which can which have adverse effects manifesting from mild agitation to death (*Karabasil et al*., 2013).

In the modern broiler meat industry, the hybrids of broilers that are being grown are genetically engineered for great productivity. The selection of hybrids is based on production characteristics, while increasingly neglecting the health of livestock (*Maslic-Strizak et al*., 2012). Despite all the changes suffered by broilers, with controlled production conditions and adequate biosecurity measures, the selectors have managed to produce broilers with breeding length reduced to 34 to 40 days, achieving a final weight of 2 to 2.8 kg, with a food conversion rate of 1.47 (*Mitrovic et al.*, 2010). The previous standard broiler breeding period lasted for 42 days, or an extended duration of 56 days (*Ramzija et al.,* 2010). No other species of domestic animals have been exposed to the extreme changes in body weight that poultry have been subjected to (*Ljubojevic et al*., 2011), whereby new ways of improving the yield and quality of broiler meat are always sought through nutrition (*Markovic et al*., 2009).

The aim of this study was to determine weight loss and temperature changes of broiler carcasses during air cooling with intermittent water spraying, as well as to determine whether there are differences among two common broiler hybrid types, and to estimate the effect of transport on weight loss.

Materials and Methods

A total of 48 birds during 6 weeks period (8 birds week^{-1}) were randomly collected from an in-line poultry processing plant that has air chilling with intermittent water spraying.

Data were collected from the slaughterhouse documentation regarding hybrid types, the ages of flocks, the length of transport and the average live bird weights.

Broiler carcasses were removed from the processing line before cooling, weighed, labeled, and returned to the cooling line. After cooling, but before packaging, the carcasses were again weighed in an identical manner. The weights of the carcasses before and after cooling were determined on calibrated electronic scales (Waagen K-PZ2-03-010).

The microclimate cooling conditions (chamber temperature, air circulation rate) were measured manually with a combined thermometer-aerometer 405-V1 Air Velocity Stick Meter (Testo, Germany).

Temperatures of the broiler carcasses were measured manually with a thermometer BT20 (Trotec, Germany). The probe was manually stabbed deep into the chest musculature, near the chest bone and directly read and recorded before and after cooling. During chilling of broiler carcasses, the highest temperature is located in the breast geometric center, where chilling effectiveness was evaluated.

Data in this case study were collected directly during the cooling process in defined conditions and then obtained results were statistically evaluated using Microsoft Office 2010, Excel 2010, and presented in Tables 1 and 2 as mean±SD.

Results and discussion

In Table 1, hybrid type, age, transport length, number of broilers examined, as well as the average weight of live broilers are presented.

Table 2 presents the weights and temperatures of broiler carcasses before and after air cooling with intermittent water spraying.

In air chilling, weight loss between 1 to 1.5% is common and can be as high as 3% depending upon the capacity and system requirements (*James et al*., 2006). In our study, weight loss was lower: 0.32% (in broilers of 2.2 kg live weight) up to 0.76% (in broilers of 2.4 kg live weight), or no weight change was recorded (in broilers 2.1 kg and lower live weight), or up to 2.18% increase of carcass weight was detected (in broilers 1.58 kg live weight). The results obtained in our study were similar to other published findings (*James et al*., 2006) on air cooling of broiler carcasses with water spray, in which post-cooling weight changes varied from −2% to +1.7%, in accordance with carcass weight.

In the United States, an increase of broiler carcass weight during cooling is not recommended. All poultry that is slaughtered and eviscerated in official establishments is chilled immediately after processing so that the internal temperature of poultry carcasses and major portions weighing less than 1.8 kg is reduced to 4.4°C or below within 4 hours of processing (*Anonymous*, 2014). Conventional chilling methods such as forced air and water immersion are used in the industry to chill poultry carcasses from approximately 40°C to 4°C, which is essential to improve safety (*Rodrigues et al*., 2014). Comparing these statements with the results obtained in our study, there was a match with temperature requirements, while there were differences in carcass weight increases, especially for the lighter weight carcasses (1.58 kg carcasses increased weight by 2.18% during air cooling with intermittent water spray).

Spraying carcasses during air chilling is not allowed in the European Union because of cross-contamination with aerosols (*Mead et al*., 2000; *Demirok et al*., 2013). Some authors claimed that air-chilled products have better microbial quality than immersion-chilled products because air chilling without water spray can injure or kill bacteria as a result of skin surface dehydration during chilling (*Berrang et al*., 2008; *Carroll and Alvarado*, 2008). In accordance with the high level of compliance of

Table 1. Hybrid type, age, transport length, number of broilers examined, and average live bird weight

Week	Hybrid type	Broiler age (days)	Transport length (km)	No of broilers examined	Average live bird weight (kg)
I	Cobb 500	41	70	8	2.40
II	Cobb 500	41	107	8	2.20
III	Cobb 500	34	79	8	1.58
IV	Cobb 500	38	79	8	2.13
V	Ross 308	38	260	8	2.11
VI	Ross 308	38	260	8	2.12

Table 2. Mean broiler carcass weights and temperatures before and after cooling, and mean percentage change of carcass weights

Week	Mean weights of carcasses before cooling (kg±SD)	Mean weights of carcasses after cooling (kg±SD)	Mean temperatures of carcasses before cooling (°C±SD)	Mean temperatures of carcasses after cooling (°C±SD)	Carcass weight change (%)
I	1.720±0.17	1.707±0.17	40.92±0.43	5.46±0.62	– 0.76
II	1.586±0.09	1.581±0.09	41.30±0.46	4.91±0.68	– 0.32
III	1.055±0.11	1.078±0.10	33.00±1.06	1.67±0.56	+ 2.18
IV	1.436±0.16	1.437±0.16	41.37±0.52	4.01±0.44	+ 0.06
V	1.202±0.19	1.204±0.19	38.93±1.27	2.41±1.15	+ 0.16
VI	1.254±0.15	1.254±0.14	39.21±1.22	2.58±0.56	/

Serbia with regard to European Union integration processes, with the ultimate goal of becoming a full member in the near or further future, urgent reforms in almost all areas have become inevitable. Certainly, the areas of food production, processing and trade cannot be bypassed (*Buncic and Rudan*, 2006). The experiences of European Union countries with well-developed and advanced standards and obligatory legislation in force, in the production of safe food, have shown that manufacturing safe food is only possible by control of the complete food chain. This control is based on the preventive approach (*Nastasijevic et al.*, 2005).

In our study, adequate cooling temperatures (1.67±0.56°C to 4.01±0.44°C) were achieved for broiler carcasses with average pre-cooling weights of 1.055±0.11 kg to 1.436±0.16 kg, respectively (Table 2). We note the latter group of broilers reached only the borderline temperature limit in accordance with domestic regulations (*Anonymous*, 1988; *Anonymous*, 2010) and foreign recommendations (*Anonymous*, 2014). Therefore, the defined conditions measured during air cooling (air flow 3.1 m sec^{-1}, air temperature −1.5°C, 120 min) with intermittent water spraying adequately cooled those broiler carcasses that weighed up to 1.436 kg before cooling, where the average live broiler weight was 2.13 kg or less.

The larger broiler carcasses, 1.586±0.09 kg to 1.720±0.17 kg reached temperatures of only 4.91±0.68°C and 5.46±0.62°C, respectively (Table 2). These temperatures after air cooling with water spraying were inadequate and did not accord with the previously mentioned regulations and recommendations.

The transport length influenced the weight loss of live broilers, but did not affect the weight loss of broiler carcasses during cooling. Also no differences were observed in accordance to the broiler hybrid type used in study (Ross-308, Cobb 500).

Conclusion

Weight loss and temperature of broiler carcasses during air cooling with intermittent water spraying depended (apart from the microclimate cooling conditions in the chamber, which were a constant temperature, air flow rate, and cooling length), on live bird weight and carcass weight. The broiler carcasses originating from birds with average live weight of 2.2 kg underwent 0.32% weight loss, and those originating from birds with average live weight of 2.4 kg lost 0.76% of weight due to cooling. Carcass weight did not change when broilers originated from birds with average live weight of 2.1 kg. The carcass weight of lighter broilers (1.58 kg average live weight) increased by 2.18% after cooling.

Adequate cooling temperatures (1.67 and 4.01°C) were achieved for broiler carcasses with pre-cooling weights of 1.055 kg (average live broiler weight of 1.58 kg) and 1.436 kg (average live broiler weight of 2.13 kg), respectively. However, since these heavier carcasses reached only 4.0°C on average, they were at the borderline temperature limit. The average temperatures of even heavier broiler carcasses (1.586 kg, average live broiler weight of 2.20 kg and 1.720 kg, average live broiler weight of 2.40 kg) were 4.91 and 5.46°C, respectively after the chilling regime examined. Therefore, these larger carcasses did not achieve adequate chill temperatures after the air cooling with water spraying.

The transport length influenced the weight loss of live birds, but did not affect the weight loss of broiler carcasses after cooling. The two broiler hybrids behaved similarly with regard to carcass weight changes after chilling.

Acknowledgements: This study was funded by grants TR 31083 and III 46009 from the Ministry of Education, Science and Technological Development, Republic of Serbia.

Disclosure Statement: No potential conflict of interest was reported by the authors.

References

Anonymous. (2014). FSIS Compliance Guide: Modernization of Poultry Slaughter Inspection: Chilling Requirements. Available at: https://www.fsis.usda.gov/wps/wcm/connect/7a0a728e-3b29-49e9-9c1b-ec55f2f04887/Chilling-Requirements-1014.pdf?MOD=AJPERES, Accessed: 06.12.2017.

Anonymous. (2014a). Rulebook on veterinary and sanitary conditions, in general and special conditions for food hygiene of animal origin, as well as conditions of hygiene of food of animal origin. *Official Gazette of the Republic of Serbia*, 25/2011 and 27/2014.

Anonymous. (2010). Rulebook on the manner of performing veterinary-sanitary inspection and control of animals before slaughter and products of animal origin, *Official Gazette of SFRY*, 68/89; *Official Gazette of the Republic of Serbia*, 10/2003, 44/2007, 91/2009, 14/2010, 68/2010.

Anonymous. (2005). Code of hygienic practice for meat CAC/RCP 58–2005.

Anonymous. (1988). Rulebook on the quality of meat of feathered livestock, *Official Gazette of SFRY*, 1/81 and 51/88.

Babic, J., D. Milicevic, D. Vranic, M. Lukic & Z. Petrovic. (2014). The effect of season of transportation on the welfare of broilers and selected parameters of broiler meat quality, *Tehnologija mesa*, *55(1)*, 46–53.

Berrang, M. E., R. J. Meinersmann, D. P. Smith & H. Zhuang. (2008). The effect of chilling in cold air or ice water on the microbiological quality of broiler carcasses and the population of *Campylobacter*. *Poultry Science*, *87*, 992–998.

Buncic, O. & A. Rudan. (2006). Legal framework and EU institutions important for food safety. *Tehnologija mesa*, *47(1–2)*, 1–7.

Cariofi, M. A. B. & B. J. Laurindo. (2007). Water uptake by poultry carcasses during cooling by water immersion. *Chemical Engineering and Processing: Process Intensification*, *46(5)*, 444–450.

Carroll, C. D. & C. Z. Alvarado. (2008). Comparison of air and immersion chilling on meat quality and shelf life of marinated broiler breast fillets. *Poultry Science*, *87*, 368–372.

Demirok, E., G. **Veluz, V. W. Stuyvenberg, P. M. Castañeda, A. Byrd & C. Z. Alvarado. (2013).** Quality and safety of broiler meat in various chilling systems. *Poultry Science*, *92*, 1117–1126.

Dufour, E. & P. J. Renou. (2002). Propriétés structurantes de l'eau dans les produits à structure cellulaire. Muscle, viande et produits carnés, M. Le Meste, D. Lorient, D. Simatos (Eds.), *Propriétés de l'eau dans les aliments*, Tec & Doc, Lavoisier 159–188.

Fluckey, W. M., M. X. Sanchez, S. R. McKee, D. Smith, E. Pendleton, & M. M. Brashears. (2003). Establishment of a microbiological profile for an air-chilling poultry operation in the United States. *Journal of Food Protection*, *66*, 272–279.

Ivanovic, S., M. Zutic & T. Kocovski. (2008). Chicken meat – foodstuff or *Campylobacter jejuni* vector. *Tehnologija mesa*, *49 (1–2)*, 46–50.

James, C., C. Vincent, I. T. de Andrade Lima & J. S. James. (2006). The primary chilling of poultry carcasses – A review. *International Journal of Refrigeration 29(6)*, 847–862.

Karabasil, N., M. Vasiljevic, M. Dimitrijevic, M. Vucinic, V. Djordjevic, J. Ivanovic & J. Kureljusic. (2013). Examining the conditions for transporting pigs to the slaughterhouse. *Tehnologija mesa*, *54(1)*, 1–7.

Ljubojevic, D., A. Bozic, S. Bjedov, N. Milosevic & V. Stanacev. (2011). The effect of extruded corn grain in the diet on broiler carcass conformation, *Tehnologija mesa*, *52(2)*, 205–211.

Maslic-Strizak, D., Lj. Spalevic, M. Raseta & I. Brankovic-Lazic. (2012). Breeding broiler chickens in the industrial poultry production, *Tehnologija mesa*, *53(1)*, 1–7.

Markovic, R., Z. M. Baltic, B. Petrujkic, D. Sefer & E. Todorovic. (2009). Influence of selenium and vitamin E on broiler meat quality and yield, *Tehnologija mesa*, *50(3–4)*, 195200.

McCarthy, Z., B. Smith, A. Fazil, J. Wu, D. S. Ryan & D. Munther. (2017). Individual based modeling and analysis of pathogen levels in poultry chilling process. *Mathematical Biosciences*, *294*, 172–180.

Mead, G. C., V. M. Allen, H. C. Burton & J. E. L. Corry. (2000). Microbial cross contamination during air chilling of poultry. *British Poultry Science, 41*, 158–162.

Mitrovic, S., V. Pupavac, V., Dj. Djermanovic & Z. Ostojic. (2010). Uticaj trajanja tova na proizvodne performanse brojlerskih pilica hibrida Cobb 500. Radovi sa XXIV savetovanja agronoma, veterinara i tehnologa, *16*, 3–4.

Nastasijevic, I., O. Lozance & L. Turubatovic. (2005). Global challenges in development of integrated control of food safety, *Tehnologija mesa*, *46(5–6)*, 225–236.

Pajic, M., N. Karabasil, D. Todorovic, D. Milanov, M. Dmitric, B. Lakicevic & V. Djordjevic. (2015). Control of *Salmonella* in primary production of broiler chickens. *Tehnologija mesa*, *56(2)*, 103–108.

Ramzija, C., M. Basic, J. Sadadinovic, A. Bozic, S. Corbo & M. Pucarevic. (2010). Study of the effect of broiler nutrition and duration of fattening on the lipid status of meat. *Tehnologija mesa*, *51(2)*, 105–14.

Rodrigues, G. G. L., M. A. B. Cariofi & B. J. Laurindo. (2014). Poultry carcasses chilled by forced air, water immersion and combination of forced air and water immersion. *Journal of Food Process Engineering, 37(6)*, 550–59.

Savell, J. W., S. L. Mueller & B. E. Baird. (2005). The chilling of carcasses. *Meat Science*, *70(3)*, 449–459.

Yang, L. L. & P. D. Smith. (2004). Moisture retention by water- and air-chilled chicken broilers during processing and cutup operations, *Poultry Science*, *83*, 119–122.

Wang, L. & D. W. Sun. (2003). Recent developments in numerical modelling of heating and cooling in the food industry – a review. *Trends in Food Science & Technology*, *14*, 408–423.

Paper received: 7.12.2017.
Paper corrected: 14.12.2017.
Paper accepted: 12.12.2017.