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THE IMPACT OF CHILLING METHODS ON MICROBIOLOGICAL QUALITY OF BROILER CARCASSES

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ABSTRACT

The aim of this work was to compare two chilling methods, combined (aerosol) and water chilling, in terms of their effectiveness in chilling of different weight categories of broiler chickens. At the same time microbial associations of different weight categories of broiler chickens were evaluated. Samples were collected in an approved establishment and poultry carcasses were divided according to weight and chilling methods into five categories. The first four categories were chilled using combined chilling method and fifth category was chilled with water. The temperature of the breast muscle before and after chilling and microbiological parameters (total viable count, *Enterobacteriaceae*, *Salmonella*) was measured. By comparing the temperature of the breast muscle after combined chilling method was not achieved in the breast muscles temperature below 4 °C in all weight categories. In any case, the lowest average temperature has been reached in the weight category <1.2 kg (4.9 °C) and with increasing weight, the average temperature was rising, and the highest was in weight category 1.8 to 2.5 kg (10.8 °C). Poultry carcasses were subsequently divided into portions and after cutting were chilled up to a temperature below 4 °C. In poultry carcasses chilled by water, the average temperature of the breast muscle after 20 minutes in the water bath was even higher (19.6 °C) compared to combine chilling. Thus chilled poultry carcasses were frozen up to -18 °C in a core of muscles. Comparing the microbiological contamination in different weight categories and chilling techniques, we found that the lowest total viable count (TVC) before and after chilling was in the lowest category and the difference before chilling was significantly lower comparing with all other categories. Conversely TVC after chilling by water was decreased. In comparing the number of *Enterobacteriaceae* before and after chilling, a similar pattern of contamination as above was found. Microbiological examination of samples of poultry carcasses did not detect the presence of *Salmonella*.

Keywords: poultry carcasses, microbiological parameters, cooling

INTRODUCTION

An important advantage of the production of poultry meat and eggs is relatively short reproductive cycle, which can be purposefully focused on seasonal market and thereby contribute to regulation of market supply and demand. Poultry consumption has increasing worldwide trend and poultry meat and products are also affordable for consumers **(Nagy, 2007)**.

Poultry farming has an irreplaceable role in ensuring rational nutrition of the population. In terms of nutritional value, poultry meat, but especially meat of gallinaceous poultry, is very important because of the high content of protein, essential amino acids, low proportion of fat, and a high proportion of essential unsaturated fatty acids, minerals, and vitamins.

Chilling of meat along with freezing are included among the priority methods used for extension of shelf life of foods. Chilling carried out immediately after slaughter and freezing minimises the growth of bacteria and therefore the microbiological contamination. As soon as the meat is cut and, where appropriate, packaged, it must be chilled to a temperature of not more than 4 °C. Meat must attain a temperature of not more than 4 °C before transport, and be maintained at that temperature during transport. Meat derived from poultry intended for freezing must be frozen without undue delay **(Commission Regulation 558/2010)**.

When carcases are subjected to an immersion chilling process, account must be taken of every precaution to avoid contamination of carcases, and taking into account parameters such as carcase weight, water temperature, volume and direction of water flow and chilling time **(Regulation 853/2004)**.

Among the indications which may optionally be used on the labelling are those concerning the method of chilling and particular types of farming **(Commission Regulation 543/2008)**.

For chilling of poultry are currently used water chilling, air chilling and combined (aerosol) chilling.

During immersion in cold water the chilling baths reduces temperature of eviscerated poultry to the desired maximum temperature of 4 °C. In case of severe microbial contamination of water may cause cross contamination of large amounts of poultry. The most common cause of contamination is poultry, in which during evisceration the digestive tract has been disrupted. In addition, cross-contaminated water (about 4-5%) is absorbed during chilling of poultry; thereby the level of microbial contamination in poultry carcasses is increased. In this way, not only increasing the number of contaminating

bacteria, but also the risk of pathogenic bacteria is occurred **(Pipová, 2011)**.

Weight loss during air chilling achieves 0.5 to 1.0%, but the hygiene benefit in comparison with chilling in water is significant. Combined chilling takes into account advantages and disadvantages of above mentioned methods of chilling. Aerosol chilling is combined with spraying of water and it is technologically identical with air chilling. Preferably, the water evaporation does not lose weight, but in the case of incomplete set of chilling parameters may take place water absorption **(Nagy et al., 2011)**.

The aim of this work was to compare two methods of chilling, combined and water chilling, in terms of their effectiveness in chilling of different weight categories of broiler chickens. At the same time microbial associations of different weight categories of broiler chickens were evaluated.

MATERIAL AND METHODOLOGY

The experiment was conducted in an approved establishment, which is subjected to the slaughtering of poultry, poultry meat cutting, production of poultry meat products, mechanically separated poultry meat and poultry freezing, chilling, subsequent storage and marketing in Slovakia and the EU. Technological line for poultry slaughtering has maximum output 6000 pcs/hour. An experiment was conducted at standard line speed 4000 pcs/hour. Poultry used in the experiment was intended for cutting after combined chilling, respectively, whole carcasses were frozen after chilling in water bath.

Combined (aerosol) chilling was carried out at a temperature of -1 to +3 °C at a pressure in the inlet jet 0.2-0.4 MPa and 1 MPa at the outlet. The capacity of the cold tunnel is 6200 pieces, which at the speed of the production line 4000 pcs/hour representing chilling time 1.5 hours, regardless of carcase weight.

Water chilling was carried out in cold water (0-4 °C) for 20 minutes; the water consumption was 1.5 litres/pc/day.

Sampling

Sampling was conducted in the summer (May-September), when the ambient temperature in operation room reached 17 to 18.5 °C. Samples were collected from broiler carcasses divided, based on weight and method of chilling, into five categories, and in each category were tested six broilers. The first four categories were chilled with combined (aerosol) method and the fifth category was chilled with water:

1. Carcasses weight <1.2 kg chilled with combined (aerosol) method.
2. Carcasses weight 1.2 - 1.5 kg chilled with combined (aerosol) method.
3. Carcasses weight 1.5 - 1.8 kg chilled with combined (aerosol) method.
4. Carcasses weight 1.8 - 2.5 kg chilled with combined (aerosol) method.
5. Carcasses weight 1.5 - 1.8 kg chilled with water.

Temperature of carcasses was measured inside the breast muscle before and after chilling respecting the line speed and the mass of broiler carcasses using Testo 105 Hand-held T-Bar thermometer (United Kingdom). Samples from carcasses were taken also for microbiological examination to assess microbial associations before and after chilling. Methods and sampling points of the carcasses for microbiological testing, as well as rules for the storage and transport are provided in **ISO 17604 (2003)**. Broiler carcasses for microbiological examinations were chosen at random, according to the selected weight categories and methods of chilling. At each sampling session samples were taken from six carcasses in each weight category and method of chilling. Samples were taken before and immediately after chilling.

Microbiological examination of samples

Samples from broiler chickens were taken aseptically. Total viable count (TVC) was determined using the pour plate method according to **ISO 4833 (2003)** and plates were incubated at 30 °C for 24-48 hours. Plate count method was used also for *Enterobacteriaceae* **(ISO 21 528-2 2004)**, and colonies were counted in a solid medium after incubation at 37 °C. Analyses were performed in two parallels. The results of all the counts are expressed as the mean values of replicates. *Salmonella* was determined in accordance with the standard procedures **(ISO 6579 2002)**.

Statistical analysis

The mean values and standard deviations were calculated by using column statistics with processing of six values for each analyzed group. Statistically significant differences between groups were calculated using t-test and one-way ANOVA analysis by Tukey comparative test in the program GraphPad Prism 5 (2007). Differences were evaluated as statistically significant when P value was <0.05.

RESULTS

Comparing breast muscle temperature before chilling, the lowest temperature was measured at the lowest weight category (<1.2 kg) and with increasing weight raised also the initial temperature of broiler carcasses. After 1.5 hours of combined chilling in a cold tunnel has not been reached in the breast muscle temperature below 4 °C in any weight category. The lowest average temperature has been reached in the weight category <1.2 kg (4.9 °C) and with increasing weight, the average temperature was rising, and in the heaviest category (1.8 to 2.5 kg) was 10.8 °C. Poultry carcasses were subsequently cut into parts, and after cutting and packing were chilled at a temperature below 4 °C. Broiler carcasses, chilled 20 minutes in water bath, reached the average temperature of breast muscles 19.6 °C. Thus chilled poultry was packed and then frozen until the meat cores had reached -18 °C.

Sampling for microbiological tests was conducted from May to September at ambient temperature in operation room from 17 to 18.5 °C and total viable count (TVC), the count of *Enterobacteriaceae* (ENT) and the presence of *Salmonella* spp. were tested.

Comparing the average values of total viable count (TVC) before and after combined chilling, except the lowest weight category (<1.2 kg), an increase in TVC was recorded ($P < 0.05$). Statistically significant increase ($P < 0.05$) in TVC and ENT microbiological parameters was found only in the heaviest weight category. Microbiological examination of the surface of poultry

carcasses chilled in water revealed decrease in TVC, while the count of ENT was similar to the combined (aerosol) chilling, and increase of microbiological contamination

Table 1 Comparison of breast muscle temperature in different weight categories of poultry before and after different methods of chilling.

Temperature °C	Combined (aerosol) chilling				Water chilling
	<1.2 kg	1.2 - 1.5 kg	1.5 - 1.8 kg	1.8 - 2.5 kg	1.5 - 1.8 kg
Before chilling	30.68	34.37	36.47	40.20	37.85
After chilling	4.97	6.73	7.85	10.88	19.67

Table 2 Comparison of microbiological parameters (log) in different weight categories of poultry before and after different methods of chilling.

Microbiological parameters log CFU.g^{-1}	Combined (aerosol) chilling				Water chilling
	< 1.2 kg	1.2 - 1.5 kg	1.5 - 1.8 kg	1.8 - 2.5 kg	1.5 - 1.8 kg
TVC before chilling	3.52^{1a}	3.99^{1b}	3.93^{1b}	3.98^{1b}	4.15^{b}
TVC after chilling	3.92^{1a}	4.28^{2ab}	4.33^{2ab}	4.42^{2b}	4.09^{ab}
ENT before chilling	2.64^{1a}	3.11^{1ab}	3.07^{1ab}	3.65^{1b}	2.79^{1a}
ENT after chilling	3.04^{1a}	2.97^{1a}	3.13^{1a}	4.01^{2b}	3.19^{2a}

[1,2] within TVC and ENT rows, different superscript numbers indicate significant differences ($P < 0.05$)

[a,b] within columns, different superscript letters indicate significant differences ($P < 0.05$)

TVC - total viable count

ENT - *Enterobacteriaceae*

CFU - colony forming units

($P > 0.05$) was found.

Comparing the average values of microbiological contamination between different weight categories and chilling methods, the lowest TVC before and after chilling was in the lowest weight category (<1.2 kg) and prior to chilling the difference was significantly lower when compared to all other categories ($P < 0.05$), while after chilling was significant difference ($P < 0.05$) only in comparison with the heaviest weight categories, in which was the largest increase of bacterial contamination. When comparing the count of ENT before chilling, statistically significant difference between the lowest and heaviest weight categories ($P < 0.05$) was found, while after chilling the difference was between the heaviest weight categories and all other categories.

The presence of *Salmonella* was not detected in either of the test samples.

DISCUSSION

The primary objective of chilling poultry is to reduce microbial growth to a level that will maximize both food safety and shelf life. Chilling, required for poultry, has been an accepted processing step in the preservation of many food commodities for numerous years **(Caroll and Alvarado, 2008)**. The two most common methods of chilling broilers are immersion chilling, in which the product is immersed in chilled (0 to 4 °C) water, and air chilling, in which carcasses are misted with water in a room with circulating chilled air **(Crews, 2006)**. Air-chilling methods use forced cold air circulation (usually 0 to 1.7 °C) to chill chicken carcasses in a tunnel-room for 90 to 150 minutes to an end carcass temperature of less than 4.4 °C. Air-chilling methods can be classified into dry and wet air-chilling (complemented with chilled water spray). Air chilling consists of two phases: during the first phase of approximately 30 minutes, very cold air is blown onto the carcasses at high velocities and during the second phase, which lasts approximately two hours, carcasses are chilled further by relatively low-velocity air at 0 °C **(Barker et al., 2004)**. Air chilling has been claimed to be the safest chilling technology and delivers a much higher-quality, better tasting, and more tender chicken, however sensory flavour and texture profiles of air-chilled broiler breast meat do not differ from those of immersion-chilled samples when the muscles are deboned at the same time after the initiation of chilling **(Zhuang et al., 2009)**.

Previous research has shown that each of the chilling methods results in a different quality of finished products, such as microbial contamination, moisture content, flavour, appearance, and meat texture **(James et al., 2006)**. Chilling of poultry carcasses is necessary to prevent microbial growth, and the United States federal regulations require that the carcass temperature must reach 4.4 °C or less within four to eight hours, depending on the post slaughter carcass weights **(USDA, 2009)**. Air chilling, although inferior to water chiling in chilling efficiency, offers great potential for quality improvement (less cross contamination and a better taste), minimizes water consumption, reduces waste water management, and is labour saving during or after chilling **(McKee, 2001)**.

The combined method of chilling by air and aerosol spraying has been developed to combine the advantages of water and air chilling methods. Cold water is sprayed onto the surface of the bodies at regular intervals, resulting in improving of heat conduction, minimizing losses and reducing the weight and the range of colour changes in the skin **(Barbut, 2002)**. **Mielnik, et al., (1999)** found that chicken chilled by aerosol chilling had a lighter and less intense yellow colour than those chilled by air chilling because the sprayed water prevented the surface from dehydrating and maintained a lighter skin colour. The internal carcass temperature was 39.9 °C at the beginning and decreased to 4 °C, with average chilling times of 55, 155, and 120 min for water chilling, air chilling, and aerosol chilling, respectively. It is commonly known that immersion carcass chilling in water (45 to 50 minutes) is more efficient and faster than chilling in air (130 to 150 minutes) **(Huezo et al., 2007)**. **Zhuang, et al., (2009)** reported that the average of initial carcass temperature, when carcasses were commercially obtained and transported to their laboratory, was 32.1 °C and reached 4 °C in 45 minutes for water chilling and in 130 minutes

for air chilling. In the current study, we noticed slightly longer times, probably because of the high initial carcass temperature (39.9 °C) upon processing on-site, different processing factors (e.g. water-to-ice ratio, velocity, or air temperature), and different carcass weights. **James, et al., (2006)** showed that the chilling time of poultry carcasses was affected by various factors, such as the carcass weight, water-ice mixture, starting temperature, air velocities, hanging conditions, temperature and humidity of the chilling room, and chilling method.

Poultry meat has a high risk of contamination during its processing. Storage temperature, type of packaging, and types and numbers of psychrotrophic bacteria are the major factors determining the spoilage of poultry meat **(Tuncer and Sireli, 2008)**. In general, the microbiological quality of air chilling poultry is better than poultry chilled water **(Barbut, 2002)**. On the contrary, in our work, we found that the water chilled poultry carcasses had a lower total viable count after chilling. Our results are supported by **Caroll and Alvarado (2008)**, when during immersion chilling, cold water flows in a counter-current direction, creating a continuous clean water system for the birds during chilling. This process provides a greater reduction in total bacterial load and results from the washing action achieved with immersion chilling. Total aerobic bacteria, coliforms, *Escherichia coli*, and *Campylobacter* were also enumerated by **Berrang, et al., (2008)** and data showed that immersion-chilled carcasses had lower numbers of bacteria; however, the difference was not large.

Allen, et al., (2000) evaluated six commercial poultry chilling systems in relation to factors affecting microbial contamination of carcasses. These systems included water immersion chilling, air chilling and air chilling with evaporative cooling using water sprays. Samples of neck skin and body cavity were taken from carcasses, together with samples from the chilling environment. These were examined for total aerobic mesophilic microbes and counts of presumptive coliform bacteria and *Pseudomonas* spp. at specific points in the chilling process. Physical measurements included surface and deep-muscle temperatures of carcasses, water temperatures and chlorine concentrations in the immersion system and air speed and temperature during air chilling. The results obtained for water immersion chilling confirmed previous experience that the washing effect reduces microbial contamination of carcasses, although initially the numbers of pseudomonads tended to increase. However, the use of water sprays tended to increase contamination of the cavity, while relatively heavy spraying using non-chlorinated water, resulted in a substantial increase in the numbers of pseudomonads. Microbial levels in the air were extremely low during all the chilling process.

CONCLUSION

Comparing temperature of breast muscles after chilling, temperature below 4 °C has not been reached in any category. In practice this means that to achieve the temperature below 4 °C, in accordance with **Regulation 853/2004**, it is necessary to adjust the speed of technological line for each weight category, and the initial classification of carcasses according to weight is required. Practically, the speed should be adjusted to the heaviest weight category (about 2.5 kg). In terms of practical applicability, it seems to be more appropriate method, when the parts of slaughtered poultry are chilled after cutting to a temperature below 4 °C according to **Commission Regulation 558/2010**, and in compliance with the principle that the process must be completed as fast as possible.

To prevent contamination of poultry carcasses after slaughtering, respectively, during chilling is necessary to comply with the principles of Good Manufacturing Practice. If chilling in water is used, cold water and possibly ice addition must be applied, and the water flow must be directed in the opposite direction to the movement of carcasses in a chilling tank.

REFERENCES

Allen, V. M., Corry, J. E. L., Burton, C. H., Whyte, R. T., Mead, G. C. 2000. Hygiene aspects of modern poultry chilling. *International Journal of Food Microbiology*, vol. 58, no. 1-2, p. 39-48. http://dx.doi.org/10.1016/S0168-1605(00)00259-2 PMid:10898460

Barbut, S. 2002. *Poultry Products Processing*. Boca Raton, FL : CRC Press, 560 p. ISBN-13: 978-1587160608.

Barker, D., Lankhaar, J., Stals, S. 2004. *5-Primary processing of poultry. Poultry Meat Processing and Quality*. Mead, G. C., CRC Press, p. 90-107. ISBN-13: 978-0849325489 http://dx.doi.org/10.1533/9781855739031.90

Berrang, M. E., Meinersmann, R. J., Smith, D. P., Zhuang, H. 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*, vol. 87, no. 5, p. 992-998. http://dx.doi.org/10.3382/ps.2007-00406 PMid:18420993

Carroll, C. D., Alvarado, C. Z. 2008. Comparison of air and immersion chilling on meat quality and shelf life of marinated broiler breast fillets. *Poultry Science*, vol. 87, no. 2, p. 368-372. http://dx.doi.org/10.3382/ps.2007-00213 PMid:18212383

Crews, J. 2006. A niche evolves. *Meat and Poultry*, p. 20-23.

Huezo, R., Smith, D. P., Northcutt, J. K., Fletcher, D. L. 2007. Effect of immersion or dry air chilling on broiler carcass moisture retention and breast fillet functionality. *Journal of Applied Poultry Research*, vol. 16, no. 4, p. 438-447. http://dx.doi.org/10.3382/japr.2006-00121

ISO 6579:2002. *Microbiology of food and animal feeding stuffs - Horizontal method for the detection of Salmonella*.

ISO 17604:2003. *Microbiology of food and animal feeding stuff - Carcass sampling for microbiological analysis*.

ISO 4833:2003. *Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of microorganisms - Colony-count technique at 30 °C*.

ISO 21528-2:2004. *Microbiology of food and animal feeding stuffs - Horizontal methods for the detection and enumeration of Enterobacteriaceae - Part 2: Colony-count method*.

James, C., Vincent, C., De Andrade Lima, T. I., James, S. J. 2006. The primary chilling of poultry carcasses - A review. *International Journal of Refrigeration*, vol. 29, no. 6, p. 847-862. http://dx.doi.org/10.1016/j.ijrefrig.2005.08.003

McKee, S. 2001. Chilling difference. *Watt Poultry USA*, vol. 12, p. 18-24.

Mielnik, M. B., Dainty, R. H., Lundby, F., Mielnik, J. 1999. The effect of evaporative air chilling and storage temperature

on quality and shelf life of fresh chicken carcasses. *Poultry Science*, vol. 78, p. 1065-1073. PMid:10404690

Nagy, J. 2007. *Poultry from stable to table* : dissertation theses. Košice, Slovak Republic : University of Veterinary medicine and Pharmacy in Košice. 60 p. ISBN-13: 978-8080770716

Nagy, J. 2011. *Hygiene of poultry, eggs and game*. 1st ed. KOŠICE, Slovak Republic : University of Veterinary medicine and Pharmacy in Košice. 386 p. ISBN-13: 978-8080772321

Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for on the hygiene of foodstuffs. OJ L 139/55, 30.4.2004.

Commission Regulation (EC) No 558/2010 of 24 June 2010 amending Annex III to Regulation (EC) No 853/2004 of the European Parliament and of the Council laying down specific hygiene rules for food of animal origin. OJ L 159/18, 25.6.2010.

Commission Regulation (EC) No 543/2008 of 16 June 2008 laying down detailed rules for the application of Council Regulation (EC) No 1234/2007 as regards the marketing standards for poultrymeat. OJ L 157/46, 17.6.2008.

Pipová, M.: *Microbial associations of poultry carcasses and poultry meat.* Nagy, J. et al. Hygiene of poultry, eggs and game. 1st ed. Košice, Slovak Republic : University of Veterinary medicine and Pharmacy in Košice. p. 204-215, ISBN-13: 978-8080772321.

Tuncer, B., Sireli, U. T. 2008. Microbial Growth on Broiler Carcasses Stored at Different Temperatures After Air- or Water-Chilling. *Poultry Science*, vol. 87, no. 4, p. 793-799. http://dx.doi.org/10.3382/ps.2007-00057 PMid:18340003

USDA. 2009. *Temperatures and chilling and freezing procedures.* 9CFR Part 381.66b. WASHINGTON, DC : Office of Federal Register, National Archives and Records Administration.

Zhuang, H., Savage, E. M., Smith, D. P., Berrang, M. E. 2009. Effect of dry-air chilling on sensory descriptive profiles of cooked broiler breast meat deboned four hours after the initiation of chilling. *Poultry Science*, vol. 88, no. 6, p. 1282-1291. http://dx.doi.org/10.3382/ps.2008-00325 PMid:19439641

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