The efficacy of air spray chilling and its impact on microbial quality of broiler carcasses

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Abstract

This study was focused on the evaluation of the period necessary for chilling of poultry carcasses through recording of temperature in the breast muscles and microbial associations on the surface in relation to body weight (BW). The temperature was measured in sixty broiler carcasses divided into six equal weight categories (1.3, 1.4, 1.5, 1.6, 1.7 and 1.8 kg). For the temperature measurements the module ELPRO was used. The module was placed in the body cavity and the probe was inserted into breast muscle. The mean temperature of breast muscles immediately after slaughter ranged from +38.8 to 40.30°C. The mean temperatures after chilling of carcasses with average BW<1.5 kg were lower than +4°C (1.30±1.17; 3.20±0.658; 3.30±0.524), but higher in carcasses with BW>1.5 kg (5.10±1.231; 7.90±2.356; 9.30±2.966). Average total viable count (TVC) on the surfaces before chilling was 4.28±0.11 CFU/100 cm² (1.2 to 1.5 log) and 3.93±0.14 log CFU/100 cm² (1.6 to 1.8). Significantly increased (P<0.05) in TVC after chilling in both weight categories (n=6) was found. Average TVC after chilling was 4.28±0.11 CFU/100 cm² (1.2 to 1.5 kg), and 4.33±0.08 (1.6 to 1.8 kg). Average Enterobacteriaceae count in the lower weight group (1.3 to 1.5 kg) was reduced from 3.11±0.35 to 2.97±2.97 during chilling, but it significantly (P<0.05) increased (3.07±0.28 to 3.15±0.14) in the higher weight group (1.6 to 1.8). Salmonella was not detected in either of the samples.

Introduction

Primary chilling of poultry carcasses is carried out to produce a safe product by reducing the temperature of the meat to a point where the rate of growth of spoilage microorganisms is reduced and the growth of most pathogenic microorganisms is prevented. It also has an effect on the major quality indicators of flavour, appearance and meat texture (James et al., 2006). Generally, a temperature of 4°C or less is achieved as soon as possible after evisceration (1 to 2 h post-mortem) (Sams and Mc Kee, 2010).

After slaughter a poultry carcass has to be chilled to reduce and then maintain the temperature of the meat below a value that will ensure a high quality, safe product (James et al., 2006). Under Regulation (EC) no 852/2004 (European Commission, 2004) after inspection and evisceration, slaughtered carcasses must be cleaned and chilled to temperature not exceeding 4°C as soon as possible, unless the meat is cut while warm. As soon as the meat is cut and, where appropriate, packaged, it must be chilled to a temperature of no more than 4°C.

The microbiological safety and rate of spoilage of chilled foods depends on what biological hazards (pathogens, etc.) are present, what other microflora are present, at what numbers they are present, whether they are on, or in, the food in question, the rate of growth of those microorganisms, the conditions of storage (temperature and gaseous atmosphere), and the characteristics (pH, aw) of the food. Temperature is by far the most important of these factors (James and James, 2014). Chilling is the last step of the process and it is aimed at lowering the temperature of the carcasses in order to control microbial growth. The two most commonly used practices are water immersion chilling and air chilling, with and without incorporation of water sprays to maintain carcass yield and enhance cooling by evaporation (Mead, 2004). Prompt and efficient chilling of the bird is essential to delay the growth of psychrotrophic spoilage bacteria and prevent any increase in microorganism of public health significance (Gracey et al., 1999).

Quick chilling of poultry carcasses slows the growth of spoilage microorganisms and therefore prolongs shelf life of the product. Furthermore, quick chilling can significantly reduce weight loss. Choice of the chilling method is therefore important for the quality of the finished product (Mielnik et al., 1999).

The aim of the present study was to evaluate the period necessary for chilling of poultry carcasses through recording of temperature in the breast muscles and microbial associations on the surface in relation to body weight (BW) of carcasses.

Materials and methods

Temperature measurement in breast muscle during air spray chilling of poultry carcasses was performed in an approved poultry slaughter plant. The temperature was measured in the broiler carcasses divided into six weight categories. Sixty measurements (ten in each weight category) of muscle temperature were recorded during air spray chilling of poultry carcasses of different weight (1.3, 1.4, 1.5, 1.6, 1.7 and 1.8 kg). The air spray chilling was carried out in the chilling tunnel at an average temperature +1.03°C and relative humidity 98.62%. In accordance with the line speed (4000 pcs/h), the time of chilling was 135 min.

The temperatures were logged using a module Elpro, type Ecolog TN 4 (ELPRO-BUCHS AG, Buchs, Switzerland) with one external probe. The carcasses of broiler chickens were taken down from the line randomly after post-mortem inspection. The module was placed into body cavity of broiler chickens and the probe was inserted into breast muscle and the chickens were labelled. After the module installation the carcasses were hanged up on the line and were chilled in a tunnel by air spray chilling method. At the end of the chilling process the carcasses were taken down...
and the module was removed. The temperature was recorded periodically in 60 s intervals. The temperatures and chilling duration recorded by the module were evaluated by software ElproLOG WIN (ELPRO-BUCHS AG). For the assessment of microbial associations before and after chilling, samples from the surfaces of chicken breast (swab samples from the area 100 cm²) of broiler carcasses were taken. The samples were taken randomly from six broiler carcasses in two weight categories (1.3 to 1.5 kg and 1.6 to 1.8 kg). Total viable count (TVC) was determined using the pour plate method according to ISO 4833 (ISO, 2003) and plates were incubated at 30°C for 24 to 48 hours. Plate count method was used also for Enterobacteriaceae (ISO 21528; ISO, 2004), and the colonies were counted in a selective-diagnostic medium (Violelet Red Bile Glucose Agar; Oxoid Ltd., Basingstoke, UK) after incubation at 37°C. Neck skins of broiler carcasses were sampled for Salmonella determination in accordance with the standard procedures (ISO 6579; ISO, 2002).

Statistical analysis

All the data were analysed statistically using GraphPad Prism software, version 5.00, 2007. The results are given as means and standard error of the mean. Statistically significant differences between groups were calculated using t-test and one-way ANOVA analysis by Tukey comparative test. Differences were evaluated as statistically significant when P<0.05.

Results and discussion

The carcass chilling process is considered to be a critical step in poultry processing. Reduction of temperature inhibits the growth of bacteria and has an influence on the physical properties of carcasses (Gumhalter Karolyi et al., 2003). The combined method of chilling is a hybrid between water and air chilling. In air chilling, the critical parameter is evaporation, whereas in water chilling, it is absorption of water. When combined, these two effects should result in unchangeable weight of the carcasses (Botka-Petrak et al., 2005).

Monitoring of temperatures during air spray chilling of poultry carcasses indicated that the mean temperature in the breast muscle at the beginning of chilling (from 38.30 to 40.30°C) should decrease to a mean temperature lower than 4°C at the end of chilling (135 min). The carcasses weighing less than 1.5 kg (from 1.3 to 1.5 kg) were chilled properly and the final mean temperature in the breast muscle was below +4°C (1.3, 3.2, 3.3°C) (Table 1). The mean duration of chilling necessary to decrease temperature to required level (≤4°C) ranged from 99 to 122 min (Table 1). Measurements in broiler carcasses with average BW higher than 1.5 kg (1.6 to 1.8 kg) showed that they were not sufficiently chilled, because the temperature in the breast muscle was higher than +4°C (Table 1). The mean temperature (5.1, 7.9, 9.3°C) recorded in poultry carcasses at the end of chilling (135 min) (Table 1 and Figure 1) was not in accordance with the temperature required by EU legislation. Jeong et al. (2011) conducted the study to investigate the effects of water chilling, air chilling, and evaporative air chilling on the moisture content, processing yield, surface colour, and visual appearance of broiler carcasses. During chilling, carcass temperature was reduced most effectively by water chilling (55 min), followed by evaporative air chilling (120 min) and air chilling (155 min). Moreover, chilling conditions can have a great impact on the development of pale, soft, exudative in poultry meat. Improper chilling (slow rate of chilling) can make carcass temperatures remain high for a longer period of time, resulting in protein denaturation and subsequent changes in meat quality (Sams and McKee, 2010).

The results obtained showed that the chilling of poultry carcasses is affected not only by basic microclimatic conditions in the chilling chamber, but also by carcass weight, initial temperature, line speed, etc. Moreover, the EU regulation may be interpreted differently, mainly in terms of time requirements, e.g. the phrase as soon as possible. In practice, the provision after inspection and evisceration, slaughtered animals must be cleaned and

| Carcass weight, kg | Temperature in the breast muscle, °C | Chilling duration up to ≤+4°C, min |
|-------------------|-------------------------------------|----------------------------------|
|                   | Before chilling                      | After chilling (135 min.)         |                                 |
| 1.3               | 39.90±1.058                         | 1.30±1.127                       | 99±13.00                        |
| 1.4               | 40.30±0.988                         | 3.20±0.658                       | 121±9.87                        |
| 1.5               | 38.30±1.520                         | 3.30±0.524                       | 122±11.24                       |
| 1.6               | 38.30±1.482                         | 5.10±1.231                       | Longer than 135 min             |
| 1.7               | 39.40±1.034                         | 7.90±2.356                       | Longer than 135 min             |
| 1.8               | 38.40±1.288                         | 9.30±2.966                       | Longer than 135 min             |

Table 1. Temperatures recorded before and after air spray chilling of poultry carcasses (n=10 per group) and time measurement necessary to achieve ≤+4°C.

Values are expressed as means ± standard deviation.

Figure 1. Changes of internal temperature of breast muscle during chilling of chicken carcasses.
chilled to no more than 4°C as soon as possible is not always correctly interpreted by food business operator.

According to the Code of Federal Regulations (2003), unlike the EU regulations, all poultry that is slaughtered and eviscerated in the official establishment shall be chilled immediately after processing so that the internal temperature is reduced to 40°F (4.4°C) or less, unless such poultry is to be frozen or cooked immediately at the official establishment. Major portions of poultry carcasses shall be chilled to 40°F (4.4°C) or lower within 4 h (carcass weight under 4 pounds/1.81 kg), 6 h (carcass weight 4 pounds/1.81 kg to 8 pounds/3.63 kg) and 8 h (carcass weight over 8 pounds/3.63 kg). This time restraint is essential, because according to many authors immediate chilling is very important for the safety and good quality of poultry meat.

Food safety and shelf-life are both important microbial concerns in relation to broiler meat production. Focus is mainly placed on the absence or control of potentially pathogenic microbes such as Salmonella spp. and Campylobacter spp. But, from the commercial point of view, other spoilage bacteria also play a role as potential threats (Voidarou et al., 2011). The primary objective of chilling poultry is to reduce microbial growth to a level that will maximise both food safety and shelf-life (Carroll and Alvarado, 2008). Table 2 shows the average values of TVC on the carcass surfaces of different weight categories before and after air spray chilling. The results of average TVC on the surfaces of broiler chickens of different weight categories before chilling were not significantly different (P<0.05). Average TVC was 3.99±0.19 log CFU/100 cm² (1.3 to 1.5 kg), and 3.93±0.14 log CFU/100 cm² (1.6 to 1.8 kg). On the contrary, a statistically significant increase (P<0.05) in TVC after chilling in both weight categories was found. Average TVC after chilling was 4.28±0.11 CFU/100 cm² (1.3 to 1.5 kg), and 4.33±0.08 (1.6 to 1.8 kg). Allen et al. (2000) concluded that the use of water sprays would not only result in cross-contamination, but could allow the transfer of organisms to carcasses from the floor and other parts of the processing environment including the shackle, which would be contaminated, particularly with Pseudomonas. Likewise Ellerbroek (1997) found a lower TVC in the air of air chiller than in an evaporative spray chiller, 3.28 log₁₀ CFU.m⁻³ and 4.16 log₁₀ CFU.m⁻³. Statistically significant increase (P<0.05) in Enterobacteriaceae average count in higher weight categories was found. Average Enterobacteriaceae count was reduced during chilling in the group with lower weight (1.3 to 1.5 kg) from 3.11±0.35 to 2.97±0.29 CFU/100 cm² but in the group with higher weight (1.6 to 1.8) increased (from 3.07±0.28 to 3.13±0.14 CFU/100 cm²) (Table 3). The results of Enterobacteriaceae count are comparable with the results of Kozačinski et al. (2006). The average number of enterobacteria in chicken breast fillets amounted to 3.62±0.48 and 2.28±0.52 log₁₀ CFU/g in chicken breasts with skin.

The trend of the counts at the different stages of the slaughter process was analysed within the same study and then compared among studies considering the same stage of the slaughter processing line. For Enterobacteriaceae the data obtained were quite controversial, and in some cases limited increases of the counts at the end of the air chilling process were reported (Barco et al., 2014). Salmonella was not detected in either of the samples.

Conclusions

This study showed that the carcasses weighing less than 1.5 kg were chilled properly and the final mean temperature in the breast muscle was in the range of 1.3 to 3.3°C depending on the BW. The mean duration of chilling necessary to decrease temperature to required level (±4°C) ranged from 99 to 122 min. Measurements in broiler carcasses with average BW higher than 1.5 kg showed that they were not sufficiently chilled, because the temperature in the breast muscle within 135 min was higher than +4°C (5.1 to 9.3°C). The results of average TVC on the surfaces of broiler chickens of different weight categories before chilling were not significantly different. Statistically significant increase in TVC after chilling in both weight categories was found instead. In higher weight categories statistically significant increase in Enterobacteriaceae average count was found. Observation of temperature regimes during processing, storage and distribution of food is a basic parameter influencing its safety and quality. A number of shortcomings exist in this particular area and their detection can be beneficial to both producers and owners and ensure additional safety and consumer satisfaction.

Table 2. Comparison of average values of total viable count on the poultry carcass surfaces of different weight categories before and after air spray chilling.

| TVC, log CFU/100 cm² | Weight category, kg |
|----------------------|---------------------|
|                      | 1.3 to 1.5          | 1.6 to 1.8          |
| Before chilling      | 3.99±0.19           | 3.93±0.14           |
| After chilling       | 4.28±0.11           | 4.33±0.08           |

TVC, total viable count; CFU, colony forming units.

Table 3. Comparison of average values of Enterobacteriaceae count on the poultry carcass surfaces of different weight categories before and after air spray chilling.

| ENT, log CFU/100 cm² | Weight category, kg |
|---------------------|---------------------|
|                     | 1.3 to 1.5          | 1.6 to 1.8          |
| Before chilling     | 3.11±0.35           | 3.07±0.28           |
| After chilling      | 2.97±0.22           | 3.13±0.14           |

ENT, Enterobacteriaceae count; CFU, colony forming units.

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