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Comparison of the effects of air and water immersion chilling on processing and sensory attributes of broiler carcass

Vergleich der Effekte von Luft- und Tauchkühlung auf Verarbeitungseigenschaften und sensorische Qualität von Broiler-Schlachtkörpern

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Summary

This study evaluated the effect of different chilling methods on processing and sensory properties, including color, moisture pickup, cooking yield, cooking loss, tenderness, marination uptake, and retention on broiler carcasses (n = 40; Ross-308). Live weight and hot carcass weight were documented. Air (2 ± 2 °C, air velocity 0.5 m/sec, relative humidity 90 %) or immersion chilling (2 ± 2 °C) was performed until a core temperature of 4 °C was attained. Carcasses were re-weighed, so as to calculate moisture uptake or loss. Then the carcass was deboned. Fillets were marinated in a vacuum tumbler for 10 minutes at 4 ˚C with 20 % w/w of saline containing 3 % NaCl. Marination uptake was measured and remaining samples were overwrapped and stored in a display chiller for 24 h to estimate marination retention. Samples were then cooked to 72 °C core temperature. For the estimation of tenderness, the Warner-Bratzler shear force method was used.

Carcasses lost 2.84 ± 0.24 % of the prechill weight in air chilling while in water immersion chilling, moisture uptake was 4.14 ± 0.46 %. In air chilling, breast color was significantly darker, redder, and more yellow in comparison to immersion chilling. Marinade pickup and marinade retention were high in air chilling. Cooking yield, loss and tenderness were not affected by the chilling method.

Keywords: chilling method, broiler carcass, color, water retention, tenderness

Introduction

Poultry is one of the most vibrant sections of the livestock sector. Poultry meat production contributes 32.7 % in the total meat production of Pakistan, while the estimated production of commercial poultry meat has reached 1391 thousand tons. The broiler production has shown an estimated increase of 10 % in 2016, having a contribution of 1.4 % share in the GDP, whereas the estimated number of broiler heads in the year 2017–2018 has reached 1057.65 million (Economic Survey, 2017–18).

In the local market, eating and buying trends are changing, and an increase in the popularity of processed meat products amongst the consumers is observed. Over the last 30 years, global meat demand and meat consumption in low to middle-income countries have tripled (USAID, 2019). This is probably due to income gains, population growth, urbanization, less available disposable time, more disposable money, and the introduction of international exotic food chains in the country with the development of the retail sector increasing consumer awareness. These market avenues have generated the demand for a safe and better quality of both fresh and processed meat products, which is, unfortunately not being met by local processors (Hussain et al., 2015). Like in other food processing industries, the chilling of carcasses is considered a critical stage for limiting and reducing the growth of pathogens to finally improving the quality of meat (James et al., 2006). In Pakistan, the most common method used for the chilling of carcasses is water immersion chilling, as it is efficient and economical. However, in water immersion chilling, most of the water is seized between skin and muscle and later dripping from the carcass during cutting and deboning (Veerkamp, 1990). Water immersed chilled carcasses could gain up to 12 % moisture of their pre-chill weight, but in subsequent operations, drip increases so that 6 % weight will be lost during cut-up and an additional 2 % during cold storage (Young and Smith, 2004). As the quality of the product is concerned, water immersion chilling improves the appearance and color of the meat (Huezo et al., 2007a). However, due to moisture retention in water immersion chilling, the carcasses demonstrate greater drip loss, thawing loss, and cooking loss.

To overcome these problems, the alternate method of air chilling is gaining popularity due to lower water uptake of the carcass and less water use (Sams, 2001). In air chilling, cross-contamination is reduced because carcasses are hung individually on the line (Fluckey et al., 2003).

The present study aims to compare the effects of water immersion chilling and air chilling on broiler meat quality parameters.

Materials and methods

A total of 40 birds were purchased from the local poultry farm, having an average weight of 1500 ± 150 g, reared under the same feeding and management system. Birds were transported under humane and stress-free conditions in the department of Meat Science and Technology for further processing. These birds‘ weight was recorded, and identification numbering was allotted.

Slaughtering was performed according to the local Halal standard (PS-3733:2016), and further processing was done under Good Hygiene Practices (GHP). Weight was recorded after skinning and after evisceration. Carcass washing was performed with potable water and allowed for dripping 5–10 minutes.

Chilling System

Carcasses were randomly assigned to one of two chilling systems, viz. “air chilling” and “water immersion chilling”. Water immersion chilling was performed in a specially designed tub in which carcasses stir automatically through paddles. The temperature of the water was attained by ice slush and maintained at 2 ± 2 °C. Carcasses (n = 20) stayed until 4 °C core temperature was achieved, noted with the help of a thermometer (TP101, Cixi Sinco, China). While half of the carcasses (n = 20) were shifted to an air chiller (at 2 ± 2 °C and 90 % relative humidity) in which the air velocity was approximately 0.5 m/sec. The temperature and humidity of air chiller were monitored with a hygrometer (6100, Electronic Temperature Instruments Ltd, UK). Carcasses were hung with the shackles in an air chiller for approximately 90 minutes for attaining an internal temperature of 4 °C.

Each of the carcass samples was weighed again for the estimation of water uptake or moisture loss. Then carcasses were shifted to the display chiller, after 4 hours, carcasses were deboned, right and left breast fillets were separated manually and then again tagged individually.

Marination

Deboned chicken fillets from both chilling methods were individually weighed and were then separately placed into a VV-T-10 vacuum tumbler (Dorit-DFT GmbH, Ellwangen, Germany) for 10 minutes at 4 °C with 20 % w/w solution of 3 % NaCl at 70 kPa (Jittinandana et al., 2005).

Parameters Studied

pH

The pH of the muscle was measured by using a pH meter with a penetrating electrode (WTW, Sentix 41 on pH 3210, WTW, Germany) at 25 °C. The pH meter was calibrated by using buffer sets 4 & 7 (WTW Technical Buffers). The probe was cleaned with distilled water after every measurement. The electrode was inserted 3 cm of the anterior end of the *pectoralis major* muscle (Ali et al., 2005). The muscle pH was measured 15 min after slaughtering, after chilling, and after breast deboning.

Color

The color was recorded by using a reflectance colorimeter (Konica Minolta® CR-410, Japan), according to Vieira and Fernandez (2014), at room temperature. Lightness (L*), redness (a*) yellowness (b*) were recorded at 15 min after slaughtering, after chilling and after breast deboning.

Marination uptake

10 breast fillets from both chilling systems were selected randomly and marinated in two batches. The marination was conducted for 10 minutes in a laboratory-grade vacuum tumbler by using a pre-chilled (4 °C) solution which included a 3 % solution of NaCl. On starting the vacuum tumbler, the pressure reduced to approximately 50 kPa. For the marination uptake and loss, the sample was weighed before and after the marination. Then marinated samples were overwrapped and stored in a display chiller for 24 hours to estimate the marination retention (Klinhom et al., 2015).

% marination uptake = (weight after marination – raw weight)/raw weight × 100

Marination Retention

Marination retention in % was calculated by the following formula:

% marination retention = [1– (marinated weight–weight after 24 h) / (marinated weight – raw weight)] x 100

Cooking loss

Each treated sample was weighed and packed in Zipline bags and cooked in a water bath (Memmert, WNB45, Germany) prewarmed to 75 °C until internal a temperature of 72 °C was reached. Final internal end-point temperatures were recorded by using a food-grade digital thermometer (Thermometer, TP101; temperature range of –50 ˚C to 300 ˚C). After cooling down to ambient temperature, samples were re-weighed, and cooking loss values were determined (Baugreet et al., 2006) according to the following formula.

% cooking loss = (weight before cooking – weight after cooking) / weight after cooking × 100

Cooking yield

The cooking yield percentage was calculated through the following formula:

% cooking yield = weight after cooking/weight before cooking × 100

Tenderness

Tenderness was measured by the Texture analyzer (TA. XT plus® stable microsystem, UK) using a V slot blade (Corzo et al., 2009). From each breast fillet, 5 strips with a cross-section of approximately 1×1 cm^2 (Height × Width) were sheared perpendicular to the muscle fiber's orientation. The amount of force required to shear fibers was given in Newton (N/cm^2) (Starkey et al., 2016). A minimum of three values was obtained from each sample.

Sensory analysis

Sensory evaluation was performed at the sensory analysis lab, Central Laboratory Complex, Ravi Campus, UVAS by trained panelists (n = 35). Chicken breast fillet samples from each treatment were cooked and specimens were further subdivided into equal parts for serving to judges. For evaluation, hedonic scale performa information was shared for clear understanding. All the samples were tagged and served warm. The panelist evaluated the following sensory parameters on 9 points hedonic scale juiciness, odor, tenderness, flavor, overall acceptability (Saha et al., 2009).

Statistical analysis

Data were analyzed through paired t-test using SAS software (version 9.2).

Results and discussion

Moisture Pickup

The effect of both chilling systems on moisture pickup results is given in Table 1. After chilling, moisture pickup in water chilling was significantly higher than in air chilling. A 4.14 ± 0.46 % increase in moisture pickup in water immersion chilling was noted, whereas it was –2.88 ± 0.24 % after 95 minutes in air chilled samples. In the primary processing industry, water immersion chilling is common as moisture uptake helps to enhance the shape and look of carcass while air chilling is beneficial for the tertiary processing industry as it causes minimum moisture loss, which helps to formulate the exact recipe with known product characteristics. In a comparable setting, Huezo et al. (2007a) reported that air-chilled carcasses losses up to 2.5 % weight in comparison to initial pre-chill weight, while in case of water immersion chilling, moisture pickup was observed to be 9.3 % and values ranging from 2.2–3.5 % and 3.4–14.7 % respectively. Likewise, in another study conducted by Young and Smith (2004), immersion chilled carcasses gained up to 4–12 % of their pre-chill weight. Similarly, Mielnik et al. (1999) reported that air-chilled carcasses lost up to 3 % of their pre-chill weight as compared to that of water immersion chilled carcass.

Marination uptake and retention

The effects of both chilling systems on marination uptake and loss are summarized in Table 2. During the process of marination, the amount of marinade absorbed by the meat is termed marination uptake, while marination retention is defined as after 24 hours of marination amount of marinade solution retained by the meat (Perumalla et al., 2011). Marination uptake in air-chilled samples was significantly higher than in the water chilled samples. Marination improves the juiciness and taste, which ultimately increases the demand for that particular value-added product. The value of marination uptake and retention in the air-chilled breast fillets was high as compared to water chilled samples with a significant p-value. Due to increased moisture loss during air chilling, breast fillets had more capacity to absorb and retain the marinade in comparison to water immersion chilled carcass which had already absorbed and held more moisture during chilling. Huezo et al. (2007a) found that marination pickup was high in air-chilled fillets as compared to water immersion chilled fillets. This was because of increased moisture loss and the ability to retain more marinade solution as compared to water immersion chilling. These results were inconsistent with the finding of Perumalla (2007), who found that marination uptake was not affected by the chilling methods. This discrepancy may be due to different salt concentrations and brine-to-product ratios, or to the use of phosphates by Perumalla (2007).

pH

The effect of both chilling systems on the pH of broiler meat is presented in Table 3. There was no significant effect of the cooling method on the pH of chicken carcasses or fillets. The pH of breast fillets declined over time with a similar trend in both treatments. These results were in line with the findings of Perumalla (2007) and Huezo et al. (2007a).

TABLE 1: *Effect of air and water immersion chilling on moisture pickup of broiler meat (g/100g) (n = 10)*

Moisture Pickup	Air chilling	Water chilling	*P*-value
	–2.84±0,24[b]	4.14±0,46[a]	<.0001

[a,b] Within rows, different superscript letters indicate statistically significant differences between means

TABLE 2: *Effect of air and water immersion chilling on marination uptake and loss of broiler meat (g/100g) (n = 10)*

Parameters	Air chilling	Water chilling	*P*-value
Marination Uptake %	11.10±0.74[a]	8.97±0.74[b]	0.031
Marination Retention %	82.52±0.94[b]	75.21±0.94[a]	<.0001

[a,b] Within rows, different superscript letters indicate statistically significant differences between means

TABLE 3: *Effect of air and water immersion chilling on pH of broiler meat (n = 20)*

Parameters	Air chilling	Water chilling	*P*-value
after 15 min of slaughtering	6.05±0.05	6.15±0,03	0.08
after chilling	6.09±0.05	6.18±0,04	0.18
after deboning	5.98±0.075	6.05±0,04	0.35

TABLE 4: *Effect of both chilling system on cooking loss, yield, and tenderness of the meat (n =10)*

Parameters	Air chilling	Water chilling	*P*-value
Cooking Loss %	22.90±0.84	23.59±0.78	0.53
Cooking Yield %	77.09±0.84	76.40±0.78	0.53
Shear Force N/cm^2	12.51±0.99	12.04±0.95	0.77

Cooking loss and tenderness

The effect of both the chilling system on cooking loss, yield, and tenderness of meat are summarized in Table 4. Cooking loss value was lower in air chilling as compared to water immersion chilling, but the p-value was >0.05. No significant effect was found in the case of cooking yield, whereas the cooking yield was high in air chilling as compared to water immersion chilling, and tenderness is the same in both chilling systems. There was no significant difference in cooking loss between both treatments. Likewise, Perumalla (2007) reported, no significant difference in cooking loss in marinated breast fillets between both chilling methods. These results support the finding of Carroll and Alvarado (2008) that air-chilled or water immersion chilled marinated breast fillets demonstrated similar cooking loss percentages. However, in other studies, air-chilled fillets had lower cooking loss than had water immersion chilled fillets (Huezo et al., 2007b; Perumalla et al., 2011). This might be because during water immersion chilling fat and body tissues were loosened, and moisture was absorbed. This water was then lost during cooking, which ultimately reduces cooking yield.

The most popular method for meat texture or tenderness measurement is by the Warner-Bratzler device (Zhuang et al., 2008). Higher shear force value is associated with less tender meat or product and vice versa. There was no significant difference in tenderness in broiler breast fillets of air and water immersion chilling. Likewise, Zhuang et al. (2008) found that chilling methods do not affect the tenderness of broiler breast fillets. Results show that air and water chilling have no significant difference in the shear force value within the same aging time, while air chilling has significantly reduced shear force value in comparison to hot boned meat. In the same way, chilling methods have no significant difference in the shear force value for cooked fillets (Dunn et al., 1995; Huezo et al., 2007a).

Color

Changes in CIE L*, a*, b*, chroma and hue values throughout the experiment are shown below in Table 5. After chilling, the L* value of water chilled samples was significantly higher than that of air chilled. Similarly, after deboning the L* value of water chilled samples and air-chilled samples were not significant. After slaughtering, a* value was significantly higher in air-chilled samples than water chilled samples. Similarly, after chilling, air-chilled samples have high significant values than that of water chilled samples. After deboning, the air chilled samples and water chilled samples had no significant values. After chilling, b* value was significantly higher in air chilling than water chilling. While after slaughtering and deboning, there was no effect on b* value. After chilling, the L* value of water chilled samples was significantly higher than that of air chilled. Similarly, after chilling, a* value of air-chilled samples was significantly higher as compared to water chilled samples. Similarly, b* value after chilling was significantly higher as compared to water immersion chilled samples. These results were consistent with the finding of Huezo et al. (2007a), reported that in case of immersion chilling, L* value of breast fillets was significantly higher (lighter) while the redness value (a*) and yellowness value (b*) was lower in comparison to air-chilled carcasses. In comparison to immersion chilled carcasses, carcasses from air-chilled treatment showed more dryness and translucent due to loss of moisture. As a result, the carcasses of air-chilled samples appeared darker than the carcasses of immersion chilled. Loss of moisture affects carcass light reflectance, and resultantly color increases the carcass redness and the yellowness. Similarly, after deboning L* value was not significantly different between chilling methods, and there was no significant difference in a* and b* value. These results were consistent with the findings of Huezo et al. (2007a, b) and Zhuang et al. (2009).

Sensory Attributes

The effect of both chilling systems on sensory attributes is given in Table 6. Chilling methods had no significant effect on tenderness and flavor. The overall impression was similar in water immersion chilled carcasses as compare to air-chilled carcasses. These results were consistent with the findings of Perumalla et al. (2011) that chilling methods had no significant effect on flavor. Hale et al. (1973) suggested that air-chilled broilers commercially processed showed a noticeable flavor as compared to immersion chilled broiler. This may be due to the retention of flavor producing compounds and nutrients during air chilling. Tender-

TABLE 6: *Effect of both chilling system on sensory attributes (scale from 1 to 10 or whatever applies Higher values indicate preference) (n=10)*

Parameters	Air chilling	Water chilling	*P*-value
Flavor	6.4±0.16	6.7±0.15	0.27
Texture	6.9±0.17	6.8±0.13	0.67
Overall Impression	6.7±0.15	7.0±0.11	0.08

TABLE 5: *Effect of air and water immersion chilling on colorimetric values (n =10)*

Time	Air chilling (AC)	Water chilling (WC)	Air chilling (AC)	Water chilling (WC)	Air chilling (AC)	Water chilling (WC)	*P*-value		
	Lightness (L*)		Redness (a*)		Yellowness (b*)		L*	a*	b*
after 15 min of slaughtering	51.32±0.84	51.72±0.78	13.86±0.28[a]	12.67±0.34[b]	12.42±0.67	0.67±0.63	0.72	0.01	0.67
After chilling	52.72±0.89[b]	55.99±1.05[a]	15.85±0.44[a]	12.05±0.35[b]	16.26±0.56[a]	10.99±0.69[b]	0.02	<.0001	<.0001
After deboning	54.05±0.58	54.40±0.78	15.67±0.28	15.37±0.34	14.79±0.79	12.97±0.72	0.77	0.51	0.08

[a,b] Within rows, different superscript letters indicate statistically significant differences between means

ness was similar in both chilling methods. Texture results were also consistent with the findings of Perumalla et al. (2011) that chilling methods, air or water did not affect tenderness. Similarly, Alvarado and Sams (2004) found that chilling methods had no significant effect on the texture of marinated breast fillets.

Conclusions

In conclusion, chilling systems had no significant effect on broiler carcass quality and sensory attributes such as tenderness, flavor, overall impression and pH. In the case of air chilling, cooking losses were relatively lower while marination uptake and retention were better but not at a statistically significant level. These results are important for the poultry processing industry as product weight losses during tertiary cause great economic losses.

Conflict of interest

The authors declare that no conflict of interest exists.

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