# Quality of intact or cut carcasses from broilers produced in the Amazon and subjected to different conservation methods

[*Qualidade de carcaças inteiras ou cortadas de frangos de corte produzidos na Amazônia e submetidos a diferentes métodos de conservação*]

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## ABSTRACT

This study aimed to assess the impact of various conservation methods on water uptake, nutritional, and microbiological content in intact or cut carcasses from broiler managed to Amazon environmental conditions. The experiment involved 48 carcasses, employing a randomized block design with a factorial scheme (2x3) based on carcass processing (intact or cut) and conservation methods (freezing, on ice, or chilling). Chilled storage led to significantly higher (p<0.05) water uptake, particularly in the short term, without adversely affecting nutritional content. Freezing yielded lower (p<0.05) water uptake, with greater (p<0.05) nutritional content, while on-ice storage exhibited satisfactory nutritional content but higher microbiological contamination. Cut carcasses displayed higher (p<0.05) short-term water uptake without detrimental effects (p<0.05) on nutrition and microbiology. Conversely, intact carcasses exhibited lower (p<0.05) water uptake in the short and long term, slightly diminished (p<0.05) nutritional content, and increased (p<0.05) microbiological contamination.

Keywords: Amazon, broilers, carcass traits, meat conservation, poultry

## RESUMO

*Este estudo teve como objetivo avaliar o impacto de vários métodos de conservação na absorção de água, no conteúdo nutricional e microbiológico em carcaças inteiras ou cortadas de frangos de corte manejados nas condições ambientais da Amazônia. O experimento avaliou 48 carcaças em delineamento em blocos ao acaso, com esquema fatorial (2x3), com os tratamentos baseados no processamento da carcaça (inteira ou cortada) e nos métodos de conservação (congelamento, gelo ou resfriamento). Nos resultados, o armazenamento refrigerado levou a uma absorção de água significativamente maior (P<0,05), particularmente em curto prazo, sem afetar negativamente o conteúdo nutricional. O congelamento proporcionou menor (P<0,05) absorção de água, com maior (P<0,05) conteúdo nutricional, enquanto o armazenamento em gelo apresentou conteúdo nutricional satisfatório, mas maior contaminação microbiológica. As carcaças cortadas apresentaram maior (P<0,05) absorção de água em curto prazo, sem efeitos prejudiciais (P<0,05) no seu conteúdo nutricional e na concentração microbiológica. Por outro lado, as carcaças inteiras exibiram menor (P<0,05) absorção de água em curto e longo prazo, conteúdo nutricional ligeiramente diminuído (P<0,05) e aumento (P<0,05) na contaminação microbiológica.*

*Palavras-chave: Amazônia, avicultura, conservação de carne, frangos de corte, rendimentos de carcaça*

## INTRODUCTION

The conservation of meat and its derivates during storage is very important to the poultry production chain (Carciofi and Laurindo, 2010; Demirok *et al*., 2013), especially to avoid significant changes in meat quality for as long as possible (Garcia *et al*., 2010; Demirok *et al*., 2013). Generally, problems during broilers meat storage are related to the environment and the processing methods applied, which may cause microbiological contamination or quality losses in all handling stages (James *et al*., 2006; Garcia *et al*., 2010).

The most used strategy to prolong the shelf life of broiler meat and its derivatives is the storage in low temperatures (chilling or freezing) (James *et al*., 2006; Demirok *et al*., 2013; Rodrigues *et al*., 2015), where these are gradually cooled after broilers slaughter, remaining in low temperatures during its processing and storage (Garcia *et al*., 2010; Pang *et al*., 2021). This method aims to delay the microbial, chemical and enzymatic activity responsible for influencing the quality of meat and its derivates (Javadi and Safarmashaei, 2011; Saranraj, 2016; Cruz *et al*., 2021).

Despite the technological evolution in the conservation and security of foods in the last decades, the diseases caused by microorganisms in foods still have been a serious problem to Public Health (Colmegna *et al*., 2009; Demirok *et al*., 2013; Saranraj, 2016; Cruz *et al*., 2021). In the poultry production chain, some pathogens are frequently diagnosed and studied in broilers meat such as *Staphylococcus aureus*, *Salmonella spp*., *Clostridium perfringens* and *Escherichia coli*. However, other groups of microorganisms also may be detected, especially due to inadequate handling and storage conditions of the broiler meat and its derivates (Colmegna *et al*., 2009; Demirok *et al*., 2013).

Front this scenario, given the significant dependence on the Amazon for importing broiler meat and its derivatives, attributed to its relatively low production compared to other Brazilian regions, it is imperative to explore and comprehend conservation protocols applicable in the Amazon to enhance the shelf life of broiler meat and its derivatives, ensuring prolonged quality retention for both locally produced and imported products from other regions. Thus, the objective of this study was to evaluate the influence of different conservation methods on the water uptake, and nutritional and microbiological content of intact or cut carcasses from broilers managed in the Amazon environmental conditions.

## MATERIAL AND METHODS

The current experiment was conducted at the Research Poultry Farm of the Federal University of Amazonas, University Campus located at Manaus city (Amazonas), Brazil. All experimental procedures were performed according to the Local Experimental Animal Care Committee and were approved (protocol number 026/2022) by the institutional ethics committee of the Federal University of Amazonas, Brazil.

Male Cobb 500 broiler carcasses were utilized in the study, raised on corn and soybean meal-based diets following Rostagno *et al*. (2017) recommendations. The broilers were managed in a commercial aviary adapted to the Amazon climate conditions with natural ventilation, surrounded by vegetation (Rufino *et al*., 2021). They were housed on a floor with pine wood shavings, provided ad libitum access to water, and their food and light were regulated as per breed guidelines. Environmental conditions during broiler management were at a temperature of 34.12±1.02ºC and a relative humidity of air at 66.31±1.31%.

At the time of slaughter (42 days old), broilers had an average body weight of 3.12±0.31kg. Following a 12-hour fast, 48 broilers were randomly chosen and euthanized through electronarcosis and bleeding. Subsequently, the hot carcasses underwent plucking, cleaning, evisceration, and immediate weighing. The carcasses were then arranged in a randomized block design using a factorial scheme (2x3). The treatments involved two carcass processing methods (intact or cut) and three carcass conservation methods (freezing, on ice, or chilling), with eight replicates for each treatment, considering each carcass as a replicate.

First, half of the carcasses (n=24) were maintained intact and individually stored in commercial standard plastic bags, while the other half was cut according to commercial cuts (neck,

breast, back, wing, thigh, and drumstick) and individually stored in commercial standard plastic bags. Second, and within the previous division, carcasses (n=8) were stored in the proposed conservation methods (freezing, on ice, or chilling).

The carcass conservation methods in this study followed the guidelines outlined in Brazilian Health Surveillance Agency's Board Resolution number 216 from September 15, 2004. Chilling was carried out in a refrigerator with a controlled temperature range of 4 to 0ºC (39.2 to 32ºF), while freezing was done in a freezer with a controlled temperature below -18 ºC (-0.4ºF). Both the refrigerator and freezer employed dry ice technology. To preserve carcasses on ice, a thermo-hygrometer with a sensor was placed in ice-filled boxes, and temperatures were measured every 12 hours to ensure control within the range of 0ºC to -18ºC (32 to -0.4ºF) in the storage environment.

After storing carcasses (intact or cut), they were removed from the controlled environment and weighed at designated intervals (24, 48, and 72 hours) to evaluate water uptake. The water uptake percentage was calculated at each interval, referencing the previous weight. After 72 hours, the final weight was compared to the initial storage weight (time 0) to calculate total water uptake. Subsequently, breast samples from each carcass were collected and promptly sent to the Fish Technology Laboratory at the Federal University of Amazonas. Following an 8-hour thaw at room temperature, the nutritional content (moisture, fat, crude protein, and ash) of the samples was determined using AOAC methods (Official…, 2019).

Furthermore, additional breast samples from each carcass were collected and promptly sent to the Laboratory of Bioactive Principles of Microbial Origin at the Federal University of Amazonas. After an 8-hour thaw at room temperature, these samples underwent microbiological analysis procedures were conducted according to the Brazilian standard normative (Brazil, 2018). Initially, a sample from each carcass was placed in a sterile container and homogenized for 60 seconds. Subsequently, 25g of this sample was added to 225mL of 1% buffered peptone water, creating standard dilutions of $10^{-1}$ and $10^{-2}$. The concentrations of

total mesophylls, molds and yeast, Staphylococcus aureus, and thermotolerant coliforms were then analyzed.

For *Salmonella spp*. detection, 1mL of selected dilutions were subjected to a pre-enrichment, being incubated at 36ºC for 16 for 20 hours. Then, the broths from the pre-enrichment were inoculated into selective broths: 0.1mL in tubes containing 10mL of Rappaport Vassiliadis and 1mL in tubes containing 10mL of Selenite Cystine broth. Subsequently, these were incubated in a water bath with constant agitation at 41°C for 24 hours. The PCR method was used to perform the diagnosis and confirm or not the presence of strains of *Salmonella* spp. in the samples (Rahn *et al*., 1992; Sambrook and Russell, 2001).

Before performing data statistical analysis, all data were tested by normality and transformed, if necessary. All data, except *Salmonella* spp. detection, were analyzed by two-way ANOVA using the R software (version 4.1.3). All commands were performed according to Logan (2010). Tukey's honestly significant difference test was used to test the significant differences among the mean values. The results are presented as means and the significant level for differences was set as $p < 0.05$.

## RESULTS

The water uptake results in the carcasses are presented in Table 1. Chilled storage resulted in a significantly higher ($p < 0.05$) short-term water uptake within the first 24 hours, followed by a notable reduction ($p < 0.05$) as storage periods increased. Freezing and on-ice storage exhibited a gradual ($p < 0.05$) increase in water uptake over the storage period, despite a long-term reduction. Chilled carcasses maintained higher ($p < 0.05$) overall water uptake compared to freezing-stored carcasses. In terms of carcass cutting, cut specimens displayed significantly higher ($p < 0.05$) short-term water uptake in the initial 24 hours, followed by a significant reduction ($p < 0.05$) with increased storage time. In contrast, intact carcasses exhibited a gradual ($p < 0.05$) water uptake with extended storage periods. Despite the long-term reduction, cut carcasses consistently demonstrated higher ($p < 0.05$) water uptake across all storage periods.

Table 1. Percentage of water uptake in intact or cut broiler carcasses stored up to 72 hours using different conservation methods

| Factors[1] | Storage times[2] | | | |
|---|---|---|---|---|
| | 24hs | 48hs | 72hs | Total |
| CM | | | | |
| Freezing | 1.79$^c$ | 4.34$^a$ | 4.68$^a$ | 7.68$^c$ |
| On ice | 7.72$^b$ | 3.60$^a$ | 4.73$^a$ | 12.45$^b$ |
| Chilling | 21.85$^a$ | 1.71$^b$ | -0.03$^b$ | 20.37$^a$ |
| PM | | | | |
| Intact | 1.50$^b$ | 4.99$^a$ | 5.31$^a$ | 8.26$^b$ |
| Cut | 19.41$^a$ | 1.44$^b$ | 0.94$^b$ | 18.74$^a$ |
| Effect | p-value | | | |
| CM[3] | 0.05* | 0.05* | 0.05* | 0.05* |
| PM[4] | 0.01* | 0.04* | 0.03* | 0.01* |
| CM x PM[5] | 0.12$^{ns}$ | 0.09$^{ns}$ | 0.01* | 0.01* |
| CV[6], % | 2.61 | 5.39 | 5.30 | 1.66 |

[1] CM – Conservation method. PM – Processing method.

[2] 24hs – water uptake after 24 hours of storage. 48hs – water uptake between 24 to 48 hours of storage. 72hs – water uptake between 48 to 72 hours of storage. Total – total water uptake after all storage periods.

[3] Averages followed by lowercase letters in the column demonstrate a significant effect of CM on the variables analyzed by Tukey's test at 0.05 significance.

[4] Averages followed by lowercase letters in the column demonstrate a significant effect of PM on the variables analyzed by Tukey's test at 0.05 significance.

[5] p-value above 0.05 demonstrates a direct influence of one factor on the result of the other and vice versa. ns – not significant.

[6] CV – Coefficient of variation.

Significant interactions were observed between factors in the water uptake of carcasses during the last evaluated interval (long-term storage - from 48 to 72 hours) and the total storage period (0 to 72 hours) (Table 2). In the long-term storage period, intact carcasses stored in freezing exhibited higher (p<0.05) water uptake, while intact carcasses stored in chilling experienced water loss. Regardless of the conservation method, cut carcasses consistently showed lower (p<0.05) water uptake in this period. However, considering all evaluated storage periods, cut carcasses demonstrated higher (p<0.05) water uptake when stored in freezing and chilling, while intact carcasses showed higher (p<0.05) water uptake when stored on ice.

Table 2. Interaction between the conservation method and processing method on the percentage of water uptake in intact or cut broiler carcasses[1]

| Broiler carcasses stored between 48 to 72 hours | | |
|---|---|---|
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 9.10$^{Aa}$ | 0.28$^{Bb}$ |
| On ice | 9.25$^{Aa}$ | 0.21$^{Bb}$ |
| Chilling | -2.42$^{Bb}$ | 2.34$^{Aa}$ |
| Broiler carcasses stored between 0 to 72 hours | | |
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | -2.27$^{Cb}$ | 17.64$^{Ba}$ |
| On ice | 22.68$^{Aa}$ | 2.23$^{Cb}$ |
| Chilling | 4.38$^{Bb}$ | 36.36$^{Aa}$ |

[1] Means followed by capital letters (columns) show a significant difference (p<0.05) between the different conservation method.

[2] Means followed by lowercase letters (lines) show a significant difference (p<0.05) between the different processing method.

The results of the nutritional content of the carcasses are presented in Table 3. Carcasses storage on ice presented a higher ($p<0.05$) percentage of fats and a lower ($p<0.05$) percentage of ashes, while carcasses storage in freezing presented a lower ($p<0.05$) percentage of fats and a higher ($p<0.05$) percentage of ashes.

Carcasses storage both on ice and in freezing presented higher ($p<0.05$) percentage of moisture than storage in chilling. Cut carcasses presented a lower ($p<0.05$) percentage of moisture, but a higher ($p<0.05$) percentage of fats and ashes values.

Table 3. Nutritional content of intact or cut broiler carcasses stored for 72 hours using different conservation methods

| Factors[1] | Variables | | | |
|---|---|---|---|---|
| | Moisture (%) | Fats (%) | Ashes (%) | Proteins (%) |
| CM | | | | |
| Freezing | 76.15[a] | 2.20[b] | 0.98[a] | 17.18 |
| On ice | 76.27[a] | 2.53[a] | 0.92[b] | 17.20 |
| Chilling | 75.63[b] | 2.24[b] | 0.95[ab] | 17.42 |
| PM | | | | |
| Intact | 76.58[a] | 2.25[b] | 0.94[b] | 17.30 |
| Cut | 75.44[b] | 2.40[a] | 0.97[a] | 17.23 |
| Effect | p-value | | | |
| CM[2] | 0.05* | 0.05* | 0.05* | 0.09[ns] |
| PM[3] | 0.05* | 0.05* | 0.05* | 0.15[ns] |
| CM x PM[4] | 0.24[ns] | 0.05* | 0.01* | 0.26[ns] |
| CV[5], % | 1.59 | 2.48 | 6.82 | 6.92 |

[1] CM – Conservation method. PM – Processing method.
[2] Averages followed by lowercase letters in the column demonstrate a significant effect of CM on the variables analyzed by Tukey's test at 0.05 significance. ns – not significant.
[3] Averages followed by lowercase letters in the column demonstrate a significant effect of PM on the variables analyzed by Tukey's test at 0.05 significance. ns – not significant.
[4] p-value above 0.05 demonstrates a direct influence of one factor on the result of the other and vice versa. ns – not significant.
[5] CV – Coefficient of variation.

It was observed significance in the interaction between the factors for the percentage of fats and ashes (Table 4). Intact carcasses stored in freezing presented a lower ($p<0.05$) percentage of fats, but a better ($p<0.05$) percentage of ashes.

Cut carcasses presented a higher ($p<0.05$) percentage of fats when stored on ice and a better ($p<0.05$) percentage of ashes when stored in chilling.

Table 4. Interaction between the conservation method and processing method on the nutritional content of intact or cut broiler carcasses stored for 72 hours[1]

| Percentage of fats (%) | | |
|---|---|---|
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 2.10[Bb] | 2.30[Ba] |
| On ice | 2.40[Ab] | 2.67[Aa] |
| Chilling | 2.26[Ba] | 2.22[Bb] |
| Percentage of ashes (%) | | |
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 0.99[Aa] | 0.97[ABb] |
| On ice | 0.93[ABa] | 0.91[Bb] |
| Chilling | 0.88[Bb] | 1.02[Aa] |

[1] Means followed by capital letters (columns) show a significant difference ($p<0.05$) between the different conservation method.
[2] Means followed by lowercase letters (lines) show a significant difference ($p<0.05$) between the different processing method.

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The results of the microbiological analysis of the carcasses are presented in Table 5. Carcasses storage in chilling presented lower (p<0.05) concentrations of molds and yeasts, aerobic mesophiles, and thermotolerant coliforms, while those stored on ice presented higher (p<0.05) concentrations. Carcasses storage in freezing presented higher (p<0.05) concentrations of *Staphylococcus aureus*. Intact carcasses presented higher (p<0.05) concentrations of *Staphylococcus aureus*, aerobic mesophiles, and thermotolerant coliforms, but lower (p<0.05) concentrations of molds and yeasts.

Table 5. Microbiological analysis of intact or cut broiler carcasses stored for 72 hours using different conservation methods

| Factors[1] | Variables[2] | | | |
|---|---|---|---|---|
| | *Staphylococcus aureus* | Molds and yeasts | Aerobic mesophiles | Thermotolerant coliforms |
| CM | | | | |
| Freezing | 82.30[a] | 35.00[b] | 4.55[b] | 0.08[b] |
| On ice | 10.25[c] | 95.00[a] | 8.80[a] | 0.16[a] |
| Chilling | 48.45[b] | 23.33[b] | 1.77[c] | 0.04[c] |
| PM | | | | |
| Intact | 91.44[a] | 43.33[b] | 6.31[a] | 0.12[a] |
| Cut | 2.55[b] | 58.89[a] | 3.76[b] | 0.06[b] |
| Effect | p-value | | | |
| CM[3] | 0.05* | 0.01* | 0.01* | 0.05* |
| PM[4] | 0.01* | 0.05* | 0.05* | 0.05* |
| CM x PM[5] | 0.05* | 0.05* | 0.05* | 0.05* |
| CV[6], % | 15.60 | 11.46 | 10.45 | 10.98 |

[1] CM – Conservation method. PM – Processing method.
[2] All values are expressed in base x10$^{-4}$.
[3] Averages followed by lowercase letters in the column demonstrate a significant effect of CM on the variables analyzed by Tukey's test at 0.05 significance.
[4] Averages followed by lowercase letters in the column demonstrate a significant effect of PM on the variables analyzed by Tukey's test at 0.05 significance.
[5] p-value above 0.05 demonstrates a direct influence of one factor on the result of the other and vice versa.
[6] CV – Coefficient of variation.

Significant interactions were observed between factors regarding the concentration of all analyzed microbiological variables (Table 6). Cut carcasses stored on ice showed higher (p<0.05) concentrations of molds and yeasts and aerobic mesophiles but lower concentrations of *Staphylococcus aureus*. Cut carcasses stored in freezing and chilling exhibited lower results. Intact carcasses stored in freezing and chilling demonstrated higher (p<0.05) concentrations of *Staphylococcus aureus* and molds and yeasts. Intact carcasses stored in freezing and on ice displayed higher (p<0.05) concentrations of aerobic mesophiles and thermotolerant coliforms.

The test conducted to detect the presence of *Salmonella* spp. revealed concentrations of this bacteria in all breast samples collected from the broiler carcasses. Considering this, it is possible to affirm that regardless of whether the carcass is intact or cut and the conservation method applied, there is the presence of *Salmonella* spp.

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Table 6. Interaction between the conservation method and processing method on the microbiological analysis of intact or cut broiler carcasses stored for 72 hours[1]

| *Staphylococcus aureus* ($x10^{-4}$) | | |
|---|---|---|
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 161.00[Aa] | 3.60[Ab] |
| On ice | 19.00[Ca] | 1.50[Cb] |
| Chilling | 94.33[Ba] | 2.56[Bb] |
| Molds and yeasts ($x10^{-4}$) | | |
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 63.33[Aa] | 6.67[Bb] |
| On ice | 26.66[Cb] | 163.33[Aa] |
| Chilling | 40.00[Ba] | 6.67[Bb] |
| Aerobic mesophiles ($x10^{-4}$) | | |
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 9.10[Aa] | 0.00[Cb] |
| On ice | 8.13[Ab] | 9.46[Aa] |
| Chilling | 1.70[Bb] | 1.83[Ba] |
| Thermotolerant coliforms ($x10^{-4}$) | | |
| Factors | Processing method[2] | |
| Conservation method[1] | Intact | Cut |
| Freezing | 0.16[Aa] | 0.00[Bb] |
| On ice | 0.20[Aa] | 0.12[Ab] |
| Chilling | 0.00[Bb] | 0.07[Aa] |

[1] Means followed by capital letters (columns) show a significant difference ($p<0.05$) between the different conservation method.
[2] Means followed by lowercase letters (lines) show a significant difference ($p<0.05$) between the different processing method.

### DISCUSSION

Considering the three conservation methods evaluated in this study, carcasses stored under chilling conditions showed a higher water uptake in the short term (first 24 hours). This observation can be attributed to various factors, including elevated pH levels and slower post-mortem glycolysis (ATP degradation). The slower chilling process of carcasses during rigor mortis, coupled with storage at temperatures close to 0°C (32°F) but not below, may contribute to this increased water uptake in the initial stages (Young and Smith, 2004; James *et al*., 2006). Additionally, a greater water uptake is observed when the meat's cut surface is minimized (Young and Smith, 2004). This phenomenon was also evident in our study, where cut carcasses exhibited higher water uptake compared to intact carcasses, especially in the short term.

It is crucial to note that existing literature highlights post-slaughter carcass conservation processes designed to preserve meat quality and organoleptic properties, thereby enhancing food safety. Chilling and freezing procedures play a vital role in the poultry production chain (Carciofi and Laurindo, 2010; Saranraj *et al*., 2016). Furthermore, the optimal conservation environment for meat preservation depends on factors such as processing time, the desired end product, or the duration required for marketing (Demirok *et al*., 2013; Saranraj *et al*., 2016).

Moreover, the greater water absorption observed with the freezing method can be attributed to several factors (Young and Smith, 2004; Carciofi and Laurindo, 2010; Demirok *et al*., 2013; Saranraj *et al*., 2016). Firstly, the formation of ice crystals during freezing can puncture cell membranes and tissue structures, leading to increased water retention in the meat. This effect is further amplified during the thawing process,

where melting ice crystals release water that gets reabsorbed by the meat, facilitating greater water uptake. Secondly, freezing can induce protein denaturation, altering the meat's structure and enhancing its water-holding capacity. Additionally, the longer storage time associated with freezing allows for more extensive water absorption compared to shorter-term chilling methods. Moreover, the larger surface area of whole carcasses, coupled with prolonged exposure to freezing temperatures, may also contribute to increased water absorption. Lastly, specific freezing conditions like temperature fluctuations and freezing rate can influence water absorption differently and warrant further investigation.

Observing the interaction of the factors, it was also possible to verify that the storage of intact carcasses in environments with very low temperatures (below 0 °C/32 °F), such as freezing or on ice storage, delays water uptake. In this scenario, the water uptake begins with a very low percentage and increases as the storage period advances. Studies by Garcia *et al*. (2010), Lee *et al*. (2014), and Pang *et al*. (2021) have reported that rapid uptake or losses of water in carcasses in the short term may lead to the denaturation of muscle proteins, resulting in imbalances in water retention and consequently affecting meat quality, potentially leading to the appearance of PSE (pale, soft, and exudative).

Considering the natural stress induced in broilers by the Amazon environment with high temperatures and relative air humidity, it is expected that these broilers exhibit lower performance and carcass traits compared to those managed in their ideal environmental conditions (Rufino and Martorano, 2020; Rufino *et al*., 2021). However, these stress levels may also have an impact on meat quality during storage due to the depletion of glycogen reserves in the muscle. This leads to the maintenance of pH above 6.2 for more than 24 hours, allowing muscle proteins to absorb more water inside the cells, resulting in DFD (dark, firm, and dry) meats (Chae *et al*., 2008; Lee *et al*., 2014), which poses a significant challenge for producers.

On the other hand, the results obtained in this study indicated that the evaluated factors (conservation method and processing method) significantly influenced the carcass moisture content separately, that is, without showing interaction between them (one factor interfering with the result of the other regarding the carcass moisture content). Thus, cut carcasses and those stored under chilling exhibited lower water absorption. In contrast, intact carcasses and those stored under freezing or on ice showed slightly higher moisture content. In this context, problems related to water uptake seem to have a more pronounced impact on organoleptic quality than on moisture content, which, in this study, exhibited results close to those typically reported in the literature. This consistency was observed irrespective of the conservation method used or whether the carcasses were cut or not (Young and Smith, 2004; Garcia *et al*., 2010; Lee *et al*., 2014; Rodrigues *et al*., 2015; Scaratti *et al*., 2016; Lorenzetti *et al*., 2019; Pang *et al*., 2021).

The nutritional content in dry matter exhibited a similar pattern, with cut carcasses showing slightly higher levels of fats and ashes. The variation in these contents among carcasses subjected to different conservation methods was minimal, observed both in individual factor analysis and their interactions with fat and mineral content. This aligns with findings reported by Katz and Dawson (1964) and Demirok *et al*. (2013): 1) Carcasses cut before chilling and/or storage tend to display greater variation in nutrient content due to high water activity (uptake and loss) in the short term and its impact on cell structure; 2) Moisture content in intact carcasses shows lower variation in the short term, gradually increasing in the long term, indicating a lesser influence on nutrient content; 3) Moisture retention by water-chilled (using ice) carcasses is highly variable, especially when carcasses are cut; and 4) Despite influencing water activity, different methods of preserving broilers' carcasses do not cause significant variations in nutrient content, emphasizing that providing a cold environment to the carcass is more crucial than the method applied (Katz and Dawson, 1964; Demirok *et al*., 2013).

Finally, it was observed that the ice conservation method led to a higher contamination of spoilage microorganisms, such as mesophilic bacteria, molds, and yeasts, specifically in cuts. This finding is consistent with previous research by Saranraj (2016) and Scaratti *et al*. (2016), who highlighted that storing carcasses under chilling conditions using ice immersion for extended

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periods can have detrimental effects. These effects range from a decline in meat quality to an elevated concentration of microorganisms. As the ice melts, the carcasses are increasingly exposed to room environmental conditions, creating an environment conducive to microbial growth and contamination. In contrast, the freezing treatment was found to influence the presence of Staphylococcus aureus in whole carcasses.

Freezing has the potential to inhibit the growth of certain bacteria, such as Staphylococcus aureus, but its effectiveness may vary against different types of microorganisms. This suggests that freezing may not be a one-size-fits-all solution for controlling microbial contamination across all carcass types. In addition, the dry ice technology provides better stable control of the temperature where the carcasses are stored, allowing them to be stored in an environment where the temperature will quickly be reduced and there will be no uncontrolled temperature fluctuations, which considerably inhibits the action of microorganisms on these carcasses, regardless of whether they are intact or cut (Javadi and Safarmashaei, 2011; Saranraj, 2016; Cruz *et al*., 2021).

High concentrations of *Staphylococcus aureus* were observed in carcasses stored in these controlled environments, in addition to the fact that all carcasses had *Salmonella* spp. This raises concerns about the microbiological safety of the carcasses. Even in these environments considered safer and with less microbial action on carcass degradation, attention should be paid to legislation protocols, especially Normative Instruction number 30 from the Brazilian Ministry of Agriculture, Livestock, and Supply (2018). This norm officializes the methods contained in the official methods manual for the analysis of food of animal origin. It is essential to verify whether these microbiological levels comply with the minimum requirements reported by this legislation to prevent hazards that could compromise the quality of the carcasses (Colmegna *et al*., 2009; Cruz *et al*., 2021).

## CONCLUSIONS

Carcass storage under chilling resulted in increased water uptake, particularly in the short-term, without affecting nutritional content.

Freezing preserved nutritional content while reducing water uptake. Ice storage maintained good nutritional content but led to higher microbiological contamination. Cut carcasses showed higher short-term water uptake with no adverse effects on nutritional or microbiological content. Intact carcasses exhibited lower short- and long-term water uptake with slightly reduced nutritional content and higher microbiological contamination.

## REFERENCES

BRAZIL. Instrução Normativa nº 30 do Ministério da Agricultura, Pecuária e Abastecimento de 26 de junho de 2018: Estabelece como oficiais os métodos contidos no manual de métodos oficiais para análise de alimentos de origem animal. Brasília, DF, 2018.

CARCIOFI, B.A.M.; LAURINDO, J.B. Experimental results and modeling of poultry carcass cooling by water immersion. *Food Sci. Technol.*, v.30, p.447-453, 2010.

CHAE, Y.S.; AHN, C.N.; YOO, Y.M. *et al*. Effect of water uptake rate of chicken on lipid oxidation, color of meat, and microbes of chicken during storage. *Korean J. Poult. Sci.*, v.35, p.247-253, 2008.

COLMEGNA, S.; INVERNIZZI, A.; MASCHER, A.L. *et al*. Microbiological characteristics of poultry meats – results of inspections carried out in the province of Milano, Italy. *Ital. J. Anim. Sci.*, v.8, p.765-770, 2009.

CRUZ, A.I.C.; BRITO, D.A.P.; COSTA, M.C. *et al*. Natural chicken meat cuts: physical and microbiological quality. *Braz. J. Dev.*, v.7, p.58430-58443, 2021.

DEMIROK, E.; VELUZ, G.; STUYVENBERG, W.V. *et al*. Quality and safety of broiler meat in various chilling systems. *Poult. Sci.*, v.92, p.1117-1126, 2013.

GARCIA, R.G.; FREITAS, L.W.; SCHWINGEL, A.W. *et al*. Incidence and physical properties of PSE chicken meat in a commercial processing plant. *Braz. J. Poult. Sci.*, v.12, p.233-237, 2010.

JAMES, C.; VINCENT, C.; ANDRADE LIMA, T.I. *et al*. The primary chilling of poultry carcasses – a review. *Int. J. Refrigeration*, v.29, p.847-862, 2006.

JAVADI, A.; SAFARMASHAEI, S. Microbial profile of marketed broiler meat. *Middle East J. Sci. Res.*, v.9, p.652-656, 2011.

KATZ, M.; DAWSON, L.E. Water absorption and retention by cut up broiler parts chilled in polyphosphate solution. *Poult. Sci.*, v.43, p.1541-1546, 1964.

LEE, J.; KIM, B.K.; JUN, J. *et al*. Comparison of water retention and loss of chicken carcasses by different water chilling condition. *Korean J. Poult. Sci.*, v.41, p.159-164, 2014.

LOGAN, M. *Biostatistical design and analysis using R*: a practical guide. New Jersey, US: John Wiley & Sons, 2010.

LORENZETTI, E.; PUTON, B.M.S.; STEFFENS, J. *et al*. Water absorption process capability analysis by chicken carcasses during precooling. *Food Sci. Technol.,* v.39, p.850-854, 2019.

OFFICIAL methods of analysis of AOAC international. 21.ed. Rockville: AOAC, 2019.

PANG, B.; YU, X.; BOWKER, B. *et al*. Effect of meat temperature on moisture loss, water properties, and protein profiles of broiler pectoralis major with the woody breast condition. *Poult. Sci.*, v.100, p.1283-1290, 2021.

RAHN, K.; GRANDIS, S.A.; CLARKE, R.C. *et al*. Amplification of an invA gene sequence of *Salmonella Typhimurium* by polymerase chain reaction as a specific method of detection of *Salmonella. Mol. Cell. Probes*, v.6, p.271-279, 1992.

RODRIGUES, L.G.G.; CARCIOFI, B.A.M.; LAURINDO, J.B. Poultry carcasses chilled by forced air, water immersion and combination of forced air and water immersion. *J. Food Process Eng.*, v.37, p.550-559, 2015.

ROSTAGNO, H.S.; ALBINO, L.F.T.; HANNAS, M.I. *et al. Tabelas brasileiras para aves e suínos*: composição de alimentos e exigências nutricionais. Viçosa: UFV, 2017.

RUFINO, J.P.F.; MARTORANO, L.G. Thermal response of broilers in different poultry house models at the Amazon environmental conditions. *Rev. Acad. Ciênc. Anim.*, v.18, p.1-7, 2020.

RUFINO, J.P.F.; MARTORANO, L.G.; CRUZ, F.G.G. *et al*. Thermal response of three strains of hens housed in a cage-free aviary at the Amazon rainforest. *Braz. J. Poult. Sci.*, v.23, n.4, 2021.

SAMBROOK, J.F.; RUSSELL, D.W. *Molecularc*: a laboratory manual. 3.ed. Nova York: Cold Spring Harbor Laboratory Press, 2001.

SARANRAJ, P.; ALFARIS, A.A.S.; KARUNYA, S.K. Preservation of broiler chicken from food borne microorganisms: a review. *Global Vet.*, v.17, p.282-294, 2016.

SCARATTI, D.; GEREMIAS, R.; FRANCHIN, P.R. *et al*. Determination of moisture levels, protein and water absorption of chicken giblets. *Braz. J. Poult. Sci.*, v.18, p.193-196, 2016.

YOUNG, L.L.; SMITH, D.P. Moisture retention by water - and air-chilled chicken broilers during processing and cutup operations. *Poult. Sci.*, v.83, p.119-122, 2004.

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