



# Mass transfer and physicochemical characteristics of turkey neck meat during dry salting

Transferência de massa e características físico-químicas da carne de pescoço de peru durante a salga seca

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The turkey neck is a cut with a higher proportion of meat when compared to the neck of other poultry, abundant in red fibers and is little valued by the food industry. It is possible to add value to this by-product through dry salting, an inexpensive and suitable method for the production of dried meat products, such as charqui. Turkey neck meat was submitted to the dry salting under different temperatures for study their salt gain and water loss on the flat plate geometry, using derived equations of Fick's Law, beyond the influence of the process in the physicochemical characteristics. The highest water loss (33.99%) occurred at 10 °C, while the highest salt gain (9.47%) was observed at 15 °C. The empirical model presented a good fit to the experimental data. Apparent diffusivities were between  $1.02 \times 10^{-10} \text{ m}^2/\text{s}$  and  $1.18 \times 10^{-10} \text{ m}^2/\text{s}$ . The dry salting promoted small decrease in pH, the darkening of the meat, while shear force increased. After the process, water activity (aw) was 0.74 and 0.79, moisture between 40.14% and 45.97%, and ash residue (12.30% - 14.03%), which characterizes a salt product with similar characteristics of charqui meat. It is possible to estimate the desirable amount of salt, producing a stable food product with a high conservation potential and a wide range of applications for derived salty products.

Keywords: poultry meat, charqui, apparent diffusivity

O pescoço de peru é um corte com alta proporção de carne quando comparado ao pescoço de outras aves, rico em fibras vermelhas e pouco valorizado pela indústria de alimentos. É possível agregar valor a este coproduto através da salga seca, um método barato e viável para a produção de produtos cárneos desidratados, como o charque. A carne de pescoço de peru foi submetida à salga seca sob temperaturas distintas para estudar o seu ganho de sal e a perda de água em geometria de placa plana, usando as equações derivadas da Lei de Fick, além da influência do processo nas características físico-químicas. Os valores mais altos de perda de água (33,99%) ocorreram a 10 °C, enquanto o ganho de sal mais alto (9,47%) foi observado a 15 °C. O modelo empírico apresentou um bom ajuste aos dados experimentais. As difusividades aparentes estiveram entre  $1,02 \times 10^{-10} \text{ m}^2/\text{s}$  and  $1,18 \times 10^{-10} \text{ m}^2/\text{s}$ . A salga seca promoveu pequena redução no pH, o escurecimento da carne, enquanto a força de cisalhamento aumentou. Após o processo, a atividade de água (aw) foi 0,74 e 0,79, umidade entre 40,14% e 45,97% e o resíduo por cinzas (12,30% -14,03%), que caracteriza um produto salgado com características similares ao charque. É possível estimar a quantidade desejável de sal, produzindo um produto alimentício estável com um alto potencial de conservação e uma ampla variedade de aplicações para produtos salgados derivados.

Palavras-chave: carne de aves, charque, difusividade aparente

## 1. INTRODUCTION

Turkey meat consumption has been linked to its nutritional value because its low cuts (breast, wing, thigh, and drumstick) have high protein content (between 19.42% until 20.84%), low lipid content (1.5% until 3.77%) and low calorie, what contributes with a healthy diet [1, 2]. Among the turkey cuts, it is observed that the neck is little valued. It is darker meat, characterized by a higher proportion of red fibers in the muscle, being a product commercialized at a low value [3]. However, due to the higher meat proportion when compared with the neck of other poultry, makes it possible to use the turkey neck in other ways.

The salted meat products are obtained through meat from butcher animals, boned or not, treated with salt, whether or not added with curing salts, seasoned or not, cooked or not [4]. The dried meat, sun-dried meat, and jerked beef are quite appreciated in several places in the world, especially in Brazil. In addition to being an important protein source obtained from less noble meat cuts, which result in a stable product with water activity around 0.75 [5, 6, 7] which is an exciting proposal for the turkey neck meat.

The mathematical modeling application in the dry salting offers essential parameters for the industrial processes. Some parameters, such salt gain, and water loss determination, evaluation of the influence of ideal temperature in the process to obtain a product with adequate salt content are essential to characterize the dry salting, as observed in other researches [7, 8, 9, 10, 11]. The empirical model proposed by Azuara et al. (1992) [12], has been widely used to describe the dehydration rate in various plant and animal foods [13] and estimate the equilibrium concentration of solutes in beef [14], chicken breast meat [10], fish [15, 16] submitted to the different osmotic solutions.

The mass transfer that occurs during the dry salting can be studied based on the cellular structure of the material, modeling the water transport according to irreversible thermodynamic processes, or through the analytical solution of Fick's Second Law for diffusion in solids of different geometries. In the latter case, it is possible to estimate the diffusion coefficient for both water and solutes involved in the process, which is the approach proposed for this work [11, 17, 18, 19, 20].

The aim of this work was to study the kinetics of salt gain and water loss by dry salting in turkey neck meat through the effect of temperature, in addition to determining the apparent diffusion coefficient of salt in the meat, and to characterize the change in pH, color, texture, moisture and ash content of turkey neck meat during the process.

## **2. MATERIAL AND METHODS**

### **2.1 Chemical analysis**

The centesimal composition was evaluated in the turkey neck meat. Moisture, ash, lipid, and protein contents were measured by AOAC methods [21]. Moisture content was determined by drying 5 g of minced meat in an oven at 105 °C. Ash content was determined by heating the residue for 3 h at 550 °C. Protein content was determined by the Kjeldahl method. Lipid content was determined using the Soxhlet extraction method. Carbohydrate content was calculated by difference.

### **2.2 Sample preparation and dry salting process**

Frozen turkey neck was subjected to thawing at 5 °C and boned manually with scalpels and cut into standard pieces in the flat plate format (3.6 cm x 6.0 cm x 4.6 cm). Dry salting was performed using commercial course-grained sodium chloride in the turkey meat cuts in the experimental apparatus built with an adaptation of the proposed by Sabadini et al. (1998) [20]. Samples were positioned on a support screen, to guarantee the unidirectional mass transfer in meat cuts, which were arranged with a bottom face in contact with the salt bed (5mm thick). A PVC film that recovered an upper face to prevent dehydration made isolation of the samples from the environment.

Dry salting was conducted at 10 °C, 15 °C, 20 °C, and 30 °C for 96 hours. The experimental device with the samples was placed inside an incubator chamber with controlled temperature (BOD Tecnal TE-371) to maintain each of the test temperatures. Sampling for moisture measurement was carried out at 0, 2, 4, and 6 hours at the beginning of the experiment, and within 12 hours until the end of the process.

### 2.3 Water loss and salt gain during dry salting

The water loss (WL) and salt gain (SG) in the salted turkey neck meat were calculated according to Schmidt, Carciofi and Laurindo (2008) [10] and Azuara et al. (1992) [12]. Treated meat samples were removed from the apparatus, and the excess salt was removed from the sample by washing with distilled water and drying with paper towels. These samples were then weighed, crushed, and analyzed to determine their moisture [21] and NaCl concentrations by the Mohr method [21]. All analyses were performed in triplicate.

Equations 1 and 2 were used to calculate the WL and SG, respectively:

$$WL = \frac{m_a - m_{a0}}{m_0} \times 100 \quad (1)$$

$$SG = \frac{m_s - m_{s0}}{m_0} \times 100 \quad (2)$$

where  $m_a$  is the water content in the sample at time  $t$ ,  $m_{a0}$  is the initial water content in the sample,  $m_0$  is the initial mass of the sample,  $m_s$  is the salt mass in the sample at time  $t$ ,  $m_{s0}$  is the initial salt mass in the sample.

The fitting to the experimental data of water loss and/or gain (WL/WG). Solids gain (SG) was performed by the Azuara et al. (1992) [12] model (Equation 3), in the linearized form [10] to determine the NaCl concentration in the turkey neck meat in the equilibrium:

$$\frac{t}{SG} = \frac{1}{k(SG^\infty)} + \frac{t}{SG^\infty} \quad (3)$$

Similarly, Equation (3) can be written for water loss. The statistical parameters used to evaluate the models were the correlation coefficient ( $R^2$ ), calculated based on the difference between the predicted gain or loss with the experimental value.

### 2.4 Apparent salt diffusivity in turkey neck meat

The apparent salt diffusivity was determined to employ an iterative process using the analytical solution of the mass conservation equation with the diffusive contribution of the Fick Law to infinite flat plate according to Equation (4). For  $D_{ap}$  estimation, it was considered that salt concentration in the equilibrium was the final concentration after the dry salting process.

$$\frac{C - C_0}{C_{ep} - C_0} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(\frac{-D_{ap}(2n+1)^2\pi^2 t}{4L^2}\right) \quad (4)$$

$C_i$  value is the solution of Equation (4), where  $C$  is the concentration of component A in the time  $t$ ,  $C_0$  is the initial concentration and  $C_{eq}$  is the concentration in the equilibrium and  $L$  is the characteristic dimension of the plate, it is assumed that in the contours of the plate ( $x=\pm L$ ), the concentration is the equilibrium concentration.

MATLAB® software (R2013a, MathWorksInc, MA, USA) was used to program the least-squares methods to minimize the  $D_{ap}$ , as a stopping criterion, the error was used in the  $10^{-6}$  space. The statistical parameter used for the model evaluation was the correlation coefficient.

### 2.5 Physicochemical analysis

The turkey neck meat physicochemical properties were evaluated during the dry salting process (0, 2, 4, 6, 12, 24, 48, 72 e 96 h) for moisture, pH, water activity, ashes, and instrumental color. In contrast, instrumental texture was performed before and after the dry salting.

The AOAC methods [21] were used to determine moisture and ash content. pH was performed by direct reading in digital pHmeter (Quimis, Diadema-SP, Brazil).

The water activity was determined at the equipment Aqualab Model 3 Series (Decagon Devices Inc., Pullman, WA, USA). The instrumental color was performed in Minolta colorimeter model CR-400 (Konica Minolta, USA). The global change ( $\Delta E$ ), which is a numerical value that is used for the difference among the parameters  $L^*$ ,  $a^*$ , and  $b^*$  of the standard measure in space, was determined through Equation (5).

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (5)$$

Shear force (N) was determined using a texturometer (TAXT Plus model, Stable Micro Systems) equipped with Warner Bratzler Shear Force (WBSP) probe.

All experiments were replicated three times. The data from physicochemical characterization of the salted turkey neck meat were evaluated by one-way ANOVA using Statistica® software (version 13.0). A post-hoc analysis was performed using Tukey test to evaluate difference among treatments at  $p < 0.05$ .

### 3. RESULTS AND DISCUSSION

#### 3.1 Chemical composition of turkey neck meat

Turkey neck meat presented moisture content below other meat products ( $69.41 \text{ g} \pm 0.33 \text{ g}$  of water/100 g sample, on wet basis). This value is little that moisture for other turkey cuts, such as leg (74.87% and 75.04%) and breast (73.23% and 74.9%) [1,22]. Lipid content found was  $6.45 \pm 0.24\%$ , superior to the chicken neck (3.60%) [23] and close to the found by Torres et al. (2000) [22] for Turkey leg cut (7.43%). Protein value was  $22.29\% \pm 0.3\%$ , close to the protein content of the Turkey wing (23.98%), and the Turkey breast (24.80%), which suggests that this cut is an excellent protein source. Ash content found was  $0.97 \pm 0.02\%$ , within the range found by Torres et al. (2000) [22] for the Turkey breast and leg (1.12% and 0.93%, respectively) and by Barbin et al. (2020) [1] for both Turkey breast and leg (1.13%). Zapata et al. (1998) [24] describe that darker cuts (chicken leg) are more abundant in calcium, iron, sodium, and zinc, and weaker in phosphorus, magnesium, and potassium when compared to light cuts (breast). NIFEXT fraction calculation presented a value of 0.88% (dashes) for the carbohydrate present in the turkey neck. This value matches carbohydrate contents found for the Turkey leg (0.81%) by Barbin et al. (2020) [1].

#### 3.2 Water loss and salt gain during dry salting process

The dry salting process promoted the meat water diffusion to the external, while the salt diffuses inside the meat matrix and was quantified in terms of water loss and salt gain during the period. Figures 1a and 1b show the water loss and salt gain during the dry salting period, determined by Equations (1) and (2), respectively.

Turkey neck meat presented an increase of variation in the water loss (WL) during the dry salting. The difference between WL among the temperatures tested was 28.01% to 33.99%. The most water loss was at 2 h of the process for all samples. This mechanism is expected, because since at the beginning of salting the concentration of saline on the surface of the meat pieces is higher, or that results in a more significant release of water, besides that the gradient of concentration between salt course and the meat is higher [25, 26, 27]. However, WL in this period (2 hours) was inversely proportional to the dry salting temperature. Lower WL was at 30 °C (4.97%), and the higher WL occurred at 10 °C (12.11%), an opposite behavior when compared with other studies that observed the temperature effect during osmotic dehydration [16, 28, 29, 30]. After the dry salting process, WL was higher at 10 °C (33.99%) when compared to the other temperatures, while WL was lower at 15 °C (23.31%). However, the diffusion properties can also be influenced by the muscle and tissue orientation, with the anisotropic behavior of salt diffusion

in muscle, as noted by Zhang et al. (2011) [31]. In Turkey's neck, the muscle and connective tissue are distributed around the bone (like a cylinder), while the deboned neck took the shape of a flat plate. Besides that, other factors, such as species and fat content in the muscle can influence the diffusion mechanism, especially in turkey neck, the lipid distribution into the meat tissue and the lipid content (6.45%, presented previously) besides containing a high proportion of connective tissue (collagen and subcutaneous, inter and intracellular fat).

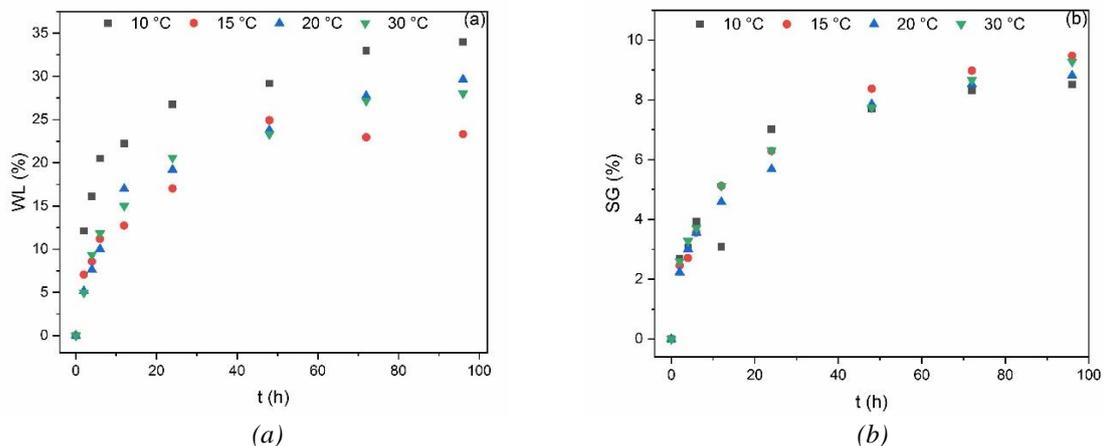


Figure 1: Water loss (WL) during the dry salting of turkey neck meat (a) and salt gain (SG) during the dry salting of turkey neck meat (b).

The salt gain in the turkey neck meat was growing, and the salt concentration after the process had little variation among temperatures tested (8.51% to 9.47%). In the first 2 hours, occurred the most salt gain (2.23% until 2.69%), where the concentration gradient at the beginning of the process is higher, and diffusion tends to decrease until the equilibrium [32]. Comparing the salt gain during each 24 hours, it was possible to observe that the most increase occurred during the first 24 hours of dry salting (7.02%; 6.29%; 5.68% and 6.31%). This effect is due to the high osmotic pressure that the Turkey neck meat was exposed, according to described by Turan et al. (2007) [33] in mussels, such as the first stage of salting. After this, from 48 h until 72 h, there was a slower increasing, which characterizes that the rate of salt intake into the turkey neck or the water loss from the meat does not have vast difference (second salting step also showed by Turan et al. (2007) [33] and finally, between 72 h and 96 h occurred the third salting step, with the minor quantity of salt into the turkey meat.

The variation in salt gain observed among the temperature used during the dry salting could be influenced by some factors. The Turkey neck meat structure is abundant both in muscle and connective tissue, heterogeneously distributed through the meat. Martínez-Lopez, Bertelsen and Jessen (2019) [34] described differences in salt diffusion between the skin and the meat during dry salting of salmon and observed that the limit between the muscle and the skin is permeable until salt to reach the saturation point and the flux is interrupted and until the system arrives at stationary state. Thus, in this work could be occurred the similar effect described by these authors, which suggested that salt intake at different rates both the skin and the muscle interfaces. Another factor related to the meat composition is the lipid content, in which Turkey neck meat presented  $6.45 \pm 0.24\%$ , which could be influenced also by the salt intake in different treatments. Czerner and Yeannes (2013) [35] verified that the initial lipid content in fish influenced inversely on mass transfer kinetics, that is, when the initial lipid content increases, the salt gain rate decreases. The Turkey neck meat presented a little variation of lipid content, but the fat tissue usually is heterogeneously distributed and could be influenced in the salt intake during the treatments tested.

The experimental data were applied to the empirical model of Azuara et al. (1992) [12]. Table 1 presents the values of water loss and salt gain and in equilibrium, the  $K_w$  and  $K_s$  constant, determined by the Equation (3), in addition to the correlation coefficient ( $R^2$ ).

The salt gain and the water loss presented proper fitting to the experimental data, with  $R^2 > 0.968$  for all fitting, except for the salt gain during the dry salting at  $T = 30$  °C, which obtained the lowest  $R^2$  (0.9032). Other authors also obtained good fitting. Schmidt, Carciofi and Laurindo (2008) [10] studied the osmotic dehydration process chicken breast and obtained a good fitting of the model to the experimental data for water loss and salt gain with Azuara et al. (1992) [12]. The empirical model also showed an excellent proper fitting for pile salting of goat sheets [36] and the osmotic vacuum dehydration of mapará fillets [29].

Table 1: Parameters estimated by Azuara's model, statistical fit parameters, and apparent diffusivity -  $D_{ap}$  ( $m^2/s$ ).

Dry salting temperature (°C)	Water Loss			Salt gain			Apparent diffusivity	
	Model parameters <sup>a</sup>		Correlation coefficient <sup>b</sup>	Model parameters <sup>a</sup>		Correlation coefficient <sup>b</sup>	Fick's Law	Correlation coefficient <sup>b</sup>
	WL <sup>∞</sup>	K <sub>w</sub>	R <sup>2</sup>	SG <sup>∞</sup>	K <sub>s</sub>	R <sup>2</sup>	D <sub>ap</sub> (m <sup>2</sup> /s)	R <sup>2</sup>
10	34.72	261.7	0.993	9.160	9.996	0.968	1.18 x 10 <sup>-10</sup>	0.944
15	25.07	98.52	0.986	10.080	11.570	0.986	1.02 x 10 <sup>-10</sup>	0.993
20	31.65	95.65	0.981	9.406	10.390	0.984	1.03 x 10 <sup>-10</sup>	0.989
30	5.17	0.427	0.873	15.86	4.024	0.9032	1.06 x 10 <sup>-10</sup>	0.989

<sup>a</sup>Parameters estimated by model from Azuara et al. [12]: water loss in the equilibrium (WL<sup>∞</sup> in g/100g) and k constant; and <sup>b</sup>correlation coefficient (R<sup>2</sup>) <sup>b</sup>statistical parameters by model from Azuara et al. [12] to the experimental data.

The k constant makes it possible to evaluate the rate in which the process reached the equilibrium. So, the higher is the k value, the higher is the mass diffusion, whether for water loss or salt gain, for time. The results show there was little difference for K<sub>w</sub> and K<sub>s</sub> at 10 °C, 15 °C and 20 °C. However, the temperature seems to have to affect K<sub>w</sub> and K<sub>s</sub> at 30 °C, respectively. Thus, the increase in temperature decreased the diffusion of water out of the meat, while the increase in temperature from 10 °C to 15 °C and 20 °C favored the salt gain.

### 3.3 Sodium chloride apparent diffusivity

The sodium chloride apparent diffusion coefficient determined for each salting temperature using the analytical solution of Fick's Law for the infinite flat plate are shown in Table 1, with the correlation coefficient, R<sup>2</sup>. The values showed little variation with the temperature (1.02 x 10<sup>-10</sup> m<sup>2</sup>/s to 1.18 x 10<sup>-10</sup> m<sup>2</sup>/s). This range of D<sub>ap</sub> is within the order of magnitude (1 x 10<sup>-10</sup> m<sup>2</sup>/s) reported in the literature for salt diffusion in meat products. Schmidt, Carciofi and Laurindo (2009) [18] found salt diffusivity values in chicken breast varying among 2.5 x 10<sup>-10</sup> m<sup>2</sup>/s and 2.9 x 10<sup>-10</sup> m<sup>2</sup>/s. Volpato et al. (2007) [11] studied the interference of NaCl and phosphate concentration in brine and the process temperature for osmotic dehydration in chicken breasts, obtaining diffusivities among 8.99 x 10<sup>-10</sup> m<sup>2</sup>/s to 9.55 x 10<sup>-10</sup> m<sup>2</sup>/s. Telis et al. (2003) [19] studied the wet salting of caiman meat from the Pantanal in different salt concentrations and under different temperatures and found values from 4.7 x 10<sup>-9</sup> to 9.62 x 10<sup>-10</sup> m<sup>2</sup>/s. Corzo, Bracho and Rodríguez (2013) [37] evaluated the pile salting of goat meat slices and found D<sub>ap</sub> values from 1.66 x 10<sup>-10</sup> m<sup>2</sup>/s to 2.44 x 10<sup>-10</sup> m<sup>2</sup>/s. Chabbouh et al. (2012) [17] evaluated the wet and drying salting in Kaddid Meat and found values among 4.081 x 10<sup>-10</sup> m<sup>2</sup>/s and 8.075 x 10<sup>-10</sup> m<sup>2</sup>/s. The differences among the studies are due to the factors that influence the water and salt diffusion, such muscle and tissue orientation, shrinkage effect, product size and geometry, temperature, salting method, the direction of the diffusion process, local molality, mathematical or empiric methods for diffusion calculation and solution/solute-to-material ratio [17, 34].

### 3.4 Physicochemical changes during the dry salting kinetics

Table 2 shows the pH for Turkey's neck meat during dry salting. The raw meat presented pH among  $5.99 \pm 0.09$  and  $6.45 \pm 0.02$  for all the treatments. This variation on pH also was observed by Chan, Omana and Betti (2011) [38] that classified the pH after 24 hours of slaughtering of turkey breast meat as low, average, and high pH meat due to the occurrence of PSE (pale, soft and exudative), standard or DFD (dark, firm and dry). Turkey meat pH also have more value than other poultry meat because the higher red fibers concentrated in the neck than the breast, which is rich in white fibers.

Since anaerobic metabolism is higher in white fibers than in red fibers, tissues rich in red fibers use less post-mortem acidification than tissues rich in white fibers. Takahashi et al. (2012) [39] showed pH values in the breast of four different lines of chickens with different ages between 5.64 and 5.92, while the pH for a leg of the same lines was between 6.04 and 6.17. However, no studies were found that relate to the pH of the turkey neck meat.

During the dry salting, pH increased 0.17 pH units at 10 °C. However, this little change was not significative ( $p > 0.05$ ). For the other temperatures, pH presented a little and significative ( $p > 0.05$ ) decrease (0.17 to 0.37 pH units). After 96 h of dry salting, pH presented range among  $5.98 \pm 0.020$  and  $6.16 \pm 0.04$ . This behavior shows that the pH was more affected significantly ( $p < 0.05$ ) in the first two hours of dry salting for the temperatures of 15 °C and 20 °C, a period in which the most considerable salt diffusion occurred, which interferes with the solubilization of myofibrillar proteins, causing changes in the pH due to the interference in the isoelectric point of the meat proteins. For the drying salting temperature of 30 °C, the significative reduction of pH occurred after 12 h of process. Temperature of the drying salting presented significative influence on the pH ( $p < 0.05$ ) only after 12h of process for treatments under 20 °C and 30 °C; while drying salting under 10 °C presented significative difference compared with other temperatures after 24 h. The samples salted under 30 °C presented significative difference to other treatments after 48 h of process.

Arnau, Guerrero and Gou (1997) [40] evaluated three salting times and three different temperatures (20, 25 and 30 °C) in dry cured ham and observed that the higher temperature (30 °C) increased the activity of proteases and also promoted a little decrease in pH and attributed to the phosphate losses stated and the salt uptake. Torres et al. (1988) [41] carried out the grinding and salting of beef after rigor mortis and observed that the application of salt in the meat caused the pH decline. Goli et al. (2011) [42] also verified a decrease of pH in the turkey meat submitted to the acidic marination. In this work, the decrease in pH was lower because the dry salting was conducted only with sodium chloride. There is no quality standard in the Brazilian Legislation for the pH of salty products. Garcia et al. (2013) [43] found for jerked beef a pH of 5.90. Assis et al. (2019) [44], reported pH values varying from 5.30 to 6.50 for several samples of commercial sun meat produced in Brazil.

The water activity ( $a_w$ ) variation during the dry salting is presented in Table 2. A significative decrease ( $p = 0.0318$ ) occurred under the range from 0.99 until (0.74-0.79) for all the treatments, showing influence of the temperature. In dry salting at 10° C, the loss in water activity was significantly higher in the first 4 h of salting, due to the more significant concentration gradient already mentioned in this salting process. The dry salting period also promoted significative reduction in water activity ( $p < 0.05$ ) was more pronounced in all samples up to 72 hours of dry salting ( $p < 0.05$ ), where in the last 24 hours  $a_w$  reduced by only 0.01 units, except for salting at 20 °C, which presented a lower  $a_w$  (0.74) and reduction of 0.02 units. This smaller gradient at the end of the process may show the beginning of the osmotic balance of turkey neck meat. Sabadini et al. (2001) [45] carried out the dry salting of meat (*M. trapezius*) for 96 h and also verified lower water activity for the salting at 20 °C (0.75) about the process carried out at 10 °C (0.79).

The final water activity for the desiccated neck remained between 0.74 to 0.79. Brazilian law stipulates a maximum limit of 0.80 for water activity in charqui. Salvá et al. (2012) [46] found  $a_w$  values for beef made from alpaca, between 0.30 and 0.73; Torres et al. (1994) [48] produced beef charqui from beef cuts with water activity ranging from 0.70 to 0.75.

Table 2: Physicochemical characteristics for Turkey neck meat at 10 °C, 15 °C, 20 °C and 30 °C, during 96 hours.

Dry salting period (h)	0	2	4	6	12	24	48	72	96
<b>Temperature (°C)</b>	<b>pH</b>								
10	5.99±0.09aA	5.97±0.18aA	6.24±0.06aA	6.21±0.13aA	6.10±0.09abA	6.20±0.02aA	6.09±0.03aA	6.04±0.11aA	6.16±0.04aA
15	6.40±0.05bA	6.12±0.11aBC	6.11±0.05aBC	6.16±0.06aB	6.10±0.03abBC	6.08±0.02abBC	6.12±0.02aBC	6.01±0.03aBC	6.11±0.04aC
20	6.45±0.02bA	6.19±0.04aB	6.11±0.02aBC	6.05±0.02aC	6.12±0.02aBC	5.94±0.09bD	6.12±0.02aBC	6.04±0.01aCD	6.08±0.02aC
30	6.15±0.02cA	6.14±0.06aA	6.13±0.05aA	6.12±0.04aAB	5.94±0.08bC	6.01±0.05bABC	5.93±0.04bC	5.88±0.06aC	5.98±0.02bBC
<b>Temperature (°C)</b>	<b>Water Activity (aw)</b>								
10	0.97±0.01aA	0.95±0.01aAB	0.89±0.06aBD	0.88±0.03aD	0.91±0.01aABD	0.85±0.02aDE	0.81±0.01aCE	0.77±0.01aC	0.76±0.01aC
15	0.99±0.00bA	0.96±0.01bAB	0.96±0.01aBD	0.92±0.01abD	0.88±0.03abABD	0.85±0.01aDE	0.79±0.00abCE	0.78±0.01aC	0.79±0.00bC
20	0.99±0.01bA	0.97±0.01cAC	0.94±0.01aC	0.94±0.01bC	0.86±0.02abB	0.84±0.01abB	0.77±0.02bD	0.76±0.01aD	0.74±0.00cD
30	0.99±0.00bA	0.97±0.01cB	0.95±0.00aBC	0.93±0.00bC	0.87±0.00bD	0.81±0.01bE	0.77±0.00bF	0.77±0.00aF	0.76±0.00aF
<b>Temperature (°C)</b>	<b>Moisture in wet basis (%)</b>								
10	70.80±0.62aA	64.52±0.33acB	61.57±1.41aB	58.12±2.22aC	56.58±1.80aC	50.76±0.47aD	49.13±0.08aD	41.76±0.99abE	41.93±0.20aE
15	69.09±0.11bA	61.91±0.27bB	60.83±0.19aBC	57.93±2.43aCD	56.50±1.30aD	51.72±1.40aE	43.82±0.74bF	46.26±0.91cF	45.97±0.85bF
20	68.55±0.78bA	63.60±0.85cB	61.48±1.17aBC	59.12±0.48aC	52.42±0.52bD	49.89±0.64aD	45.04±2.09bcE	41.65±0.53aF	40.14±1.86aF
30	71.13±0.00aA	65.77±0.00cB	61.53±0.00aC	59.92±0.00aC	56.21±0.00aD	50.68±0.00aE	47.93±0.00cF	44.07±0.01bcG	42.96±0.02abG
<b>Temperature (°C)</b>	<b>Ash content (%)</b>								
10	1.00±0.03aA	4.14±0.40aB	5.84±1.27aC	5.66±0.44aC	7.04±0.73aD	11.50±0.56aE	13.07±0.43aF	13.74±0.58aF	14.03±0.30aF
15	0.95±0.03aA	4.61±0.51aB	5.13±0.25aB	6.51±0.36bBC	8.48±0.23bCD	10.84±0.25aDE	13.05±0.50aE	13.61±0.32aE	12.30±5.74aE
20	1.02±0.06aA	4.22±0.48aB	5.46±0.24aB	6.19±0.10abBC	7.96±0.28abCD	9.78±0.24aD	12.80±3.62aE	13.49±0.25aE	13.84±1.05aE
30	1.05±0.00aA	4.56±0.03aB	5.48±0.06aB	6.03±0.01abBC	7.75±0.02abCD	9.03±0.02bDE	12.74±0.08aEF	12.43±0.01bEF	13.66±0.06aF
<b>Temperature (°C)</b>	<b>Global color change (ΔE)</b>								
10	0	10.16±3.08aA	9.84±3.28aA	12.34±3.53aA	12.08±6.57aA	17.91±1.76aA	17.17±3.80aA	19.26±2.41aA	18.51±3.87aA
15	0	7.32±1.20aA	7.49±3.07aA	8.14±1.54aAB	9.51±0.28aAB	11.37±1.07aAB	9.94±1.56aAB	12.09±2.91aAB	13.38±1.73aB
20	0	11.05±0.49aAB	10.34±0.87aB	11.95±2.03aAB	12.42±0.49aAB	13.39±1.67aAB	14.32±1.49aAB	14.93±1.89aA	14.53±2.14aAB
30	0	12.90±3.05aA	12.81±4.25aA	10.52±3.00aA	14.90±2.06aA	15.09±2.48aA	11.80±0.90aA	11.31±0.79aA	12.97±3.23aA

Lowercase letters between lines differ on the temperature. Uppercase letters between columns differ on the dry salting period. P<0.05.

The sun meat goes through softer salting, which results in a product with higher water activity, around 0.92, varying according to the processing techniques. The final water activity obtained for the salted turkey neck classifies the final product as charqui [26, 46, 47, 48].

The average of initial moisture (Table 2) was around  $69.48 \pm 1.13\%$ ; this value is slightly less than the moisture found by other studies, such as leg (74.87% and 75.04%) and for breast (73.23% and 74.9%) [1, 22]. This difference can be explained by the exudation of the turkey neck during thawing and deboning. The temperature of dry salting ( $p=0.004$ ) influenced the moisture values in some periods of the process (except in 4 h, 6 h and 24 h), while the period of the dry salting ( $p<0.05$ ) influenced significantly in the moisture of the samples. It was observed that in the first hours, the moisture loss was more significant, stabilizing with the processing period, which demonstrates that the meat parts were tending to balance. After 72 h of salting, the moisture varied in the range of 1% (not significant –  $p>0.05$ ) for all treatments.

Biscontinini et al. (1996) [49] presented a wet salting mechanism that explains the change that occurs in the tissue during the production of jerked beef. After the uniform distribution of salt through the tissue, swelling occurs by absorbing water from the brine to dilute the salt. Reaching 15% of the final salt concentration, band A is extracted, and myosin is unable to retain water. The depolymerization of the myosin, together with the osmotic pressure, favors the migration of water from the myofibrillar spaces to the interfibrillar spaces, going to the extracellular compartments and finally escaping to the meat surface. At the end of the process, the intercellular space shrinks, and the extracellular space increases, which favors the drainage of saline solutions. Dry salting did not involve initial water absorption, only loss as the results for water loss show throughout the process. The final moisture of the turkey neck after 96 h of salting was within limits established by Brazilian Legislation for charqui (50% on a wet basis), with a temperature of 15 °C having the highest value for moisture ( $45.97 \pm 0.85\%$ ), while samples dried at 20 °C showed lower moisture ( $40.14 \pm 1.86\%$ ) [47].

The ash content in the raw turkey neck obtained in this work (Table 2) was within the range found by Torres et al. (2000) [22] for the turkey breast and leg (0.93 and 1.12% respectively), in addition to the range found by Barbin et al. (2020) [1] for both Turkey breast and leg (1.13%). It is noted that in the first 24 h of salting the meat absorbed the salt quickly, representing the significant increase ( $p<0.05$ ) in ash that the samples had in that period. Upon reaching 48 h of salting, the ash content started to stabilize, indicating that the tissue was reaching balance in terms of water loss and salt gain [22]. In the general context, the temperature of dry salting did not influence the ash content. However, there were significant differences ( $p<0.05$ ) for ash content between 10 °C and 15 °C at 12 h; 30 °C at 24 h and 72 h, respectively. This little variation could be related to the salt gain during the dry salting process, as previously stated, the salt diffusion can be affected by the stage of the salting [32], nature and composition of the meat tissue [33, 34, 35]. The turkey neck after 96 h of salting showed 13.45% of fixed mineral residue (ash) for all treatments, where the Brazilian Legislation establishes a maximum limit of 23% for charqui [47].

The global color change ( $\Delta E$ ) is shown in Table 2. It was observed that the increase in temperature caused a not significant decrease ( $p>0.05$ ) in color variation after the process (mainly in the treatment at 30 °C), while in the other evaluated salting temperatures,  $\Delta E$  was higher and increasing significantly ( $p<0.05$ ) during the dry salting time (at 10 °C, 15 °C and 20°C). Thus, the temperature of the dry salting did not affect significantly the global change ( $p>0.05$ ), except for the conditions (15°C/96h and 20°C/72h). However statistically the color difference was not significant with the dry salting period for all treatments (at 10 °C and 30 °C), this parameter increased proportionally with the concentration of salt in the process and also the fact of the samples analyzed are destructive, increased the standard deviation of the measurement, which influenced on the not significant differences. For all temperatures it was noted that in the last hours of salting there was a not significant slight variation in the values of  $\Delta E$  (between 0.14 to 1.29 units). Bampi, Schmidt and Laurindo (2019) [50] salted beef with reduced sodium content and found values of global color difference between 7.79 to 14.15, in which the increase in the salt content used during the process promoted more considerable color change. Still in the study by Bampi, Schmidt and Laurindo (2019) [50],  $\Delta E$  values between 6.0 and 12.0 show a massive color difference, and above 12.0 units, the difference is classified as very large.

This global variation is a result of the variations observed in the parameters  $L^*$ ,  $a^*$ , and  $b^*$  (data not shown, used by Equation 5 to calculate  $\Delta E$ ). There was a loss of luminosity in all samples (reduction of the parameter  $L^*$ ), which characterizes the darkening of the meat, and it was noted that the luminosity loss was higher at 10 °C and was lower with the increase in temperature evaluated. The  $a^*$  parameter for all treatments was positive, which indicates the tendency to red meat. However,  $a^*$  decreased during the salting period, indicating a reduction in the intensity of the red color during the process. Yalçın and Şeker (2016) [51] also observed a decrease in the parameter  $a^*$  after the salting of turkey breast. Sabadini et al. (2001) [45] found a drop in the three-color parameters during the wet salting of meat. The tendency towards yellow color, represented by positive values of  $b^*$ , was higher in samples submitted to lower salting temperatures. In contrast,  $b^*$  was lower (in the range of 4 units) and constant during salting only at 30 °C.

The results found to confirm that, in fact, salt exerted a direct influence on the color change of turkey neck meat. The salt influences the color of the meat by two pro-oxidant mechanisms, where the salt increases the oxidation potential of myoglobin and reduces the surface tension of the meat's oxygen, favoring the oxidation of myoglobin to metmyoglobin that has a brownish color [45, 52].

The shear force tests were carried out for fresh meat and after 96 h of dry salting. The small variation in fresh meat used in all treatments is due to the different batches from the turkey neck, with an average shear force of  $94.36 \pm 15.28$  N. The shear force increased significantly for all samples ( $p < 0.05$ ), regardless the tested temperatures ( $p > 0.05$ ), where at 10 °C the shear force evolved from  $95.28 \pm 19.99$  N<sup>AA</sup> to  $163.18 \pm 7.67$  N<sup>AB</sup>; at 15 °C ( $87.59 \pm 7.86$  N<sup>AA</sup> for  $175.00 \pm 18.15$  N<sup>AB</sup>); 20 °C ( $100.21 \pm 18.74$  N<sup>AA</sup> for  $180.30 \pm 17.94$  N<sup>AB</sup>) and at 30 °C ( $84.88 \pm 6.67$  N<sup>AA</sup> for  $168.63 \pm 13.27$  N<sup>AB</sup>), respectively. In addition to the water loss, the salt gain promotes an increase in the hardness in the meat, where at 15 °C and 20 °C, the highest hardness of the samples was observed, combined with the more significant salt gains and higher water losses during dry salting (Figure 1b). The results demonstrate that during the salting the meat's hardness increased, as predicted by Ruiz-Ramírez et al. (2005) [53], who associated the increase in hardness to the water loss by the muscle, which in turn is related to the salt content and the pH of the tissue. In addition to the water loss, the salt also increases the hardness of the tissues because high concentrations of NaCl promote the compaction of the myofibrillar structure and produce an inhibitory effect on the activity of calpain that works by breaking the Z lines and increasing the tenderness of the meat [52]. Bampi, Schmidt and Laurindo (2019) [50] during the dry salting of beef cuts found values ranging from 117 N to 287 N with different drying methods, which demonstrates that the dehydration method and the form of incorporation of the solutes result in different textures.

#### 4. CONCLUSION

The dry salting process of turkey neck cuts can be done at good salt gain rates and water loss rate, with process time of 96 h. These cuts present moisture content approximately 42% and water activity near 0.76, similar of the charqui. The salt concentration in the final product had little variation between 8.51% and 9.47%. The apparent diffusion coefficient for turkey neck meat showed little variation between the temperatures tested and was compatible with other meat products mentioned in the literature. The salt impregnation caused color changes and darkening in the cut meats as shown by the decrease of the  $L^*$ ,  $a^*$ , and  $b^*$  color parameters. The apparent diffusion coefficient for turkey neck meat showed little variation between the temperatures tested and was compatible with other meat products mentioned in the literature. Therefore, dry salting process has great potential for development new products such as shredded dried meat, meat sausages, among others.

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