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Original Article

Comparative study of the quality of breast meat of free-range chicken (*Gallus gallus domesticus*) and conventional chicken (*Gallus gallus*)

Estudo comparativo da qualidade da carne de peito de frango caipira (*Gallus gallus domesticus*) e frango de granja (*Gallus gallus*)

C. Lopes[a], F. A. R. Cardoso[b,c]*, P. S. Mendes[c] and A. A. Droval[c]

[a] Universidade Tecnológica Federal do Paraná – UTFPR, Departamento de Engenharia de Alimentos, Campo Mourão, PR, Brasil
[b] Universidade Tecnológica Federal do Paraná – UTFPR, Programa de Pós-graduação em Inovações Tecnológicas – PPGIT, Campo Mourão, PR, Brasil
[c] Universidade Tecnológica Federal do Paraná – UTFPR, Programa de Pós-graduação em Tecnologia de Alimentos – PPGTA, Campo Mourão, PR, Brasil

Abstract

This study compares the physicochemical characteristics of breast meat (*Pectoralis major*) from conventional chicken and free-range chicken production systems. Analyses of pH, instrumental color measurement, weight loss from cooking (WLC), and water retention capacity (WRC) were carried out. Average pH values were slightly higher for conventional chicken samples. WLC did not show a significant difference between conventional and free-range chicken samples. The WRC was better and higher for the free-range chicken samples than the conventional ones. The mean values for luminosity (L*) were within the normal range, with slightly higher values for conventional chicken. In chromatids a* and b*, there was a tendency towards a more reddish color for free-range chicken samples. The differences found for types of production can be explained mainly by the difference in age at slaughter, the degree of physical activity, animal feeding, among other characteristics that differentiate an animal raised by the extensive system from the intensive system.

Keywords: production, chickens, quality, WRC, WLC.

Resumo

Este estudo compara as características físico-químicas da carne de peito (*Pectoralis major*) de frangos de granja e caipiras. Foram realizadas análises de pH, medição de cor instrumental, perda de peso por cocção (PPC) e capacidade de retenção de água (CRA). Os valores médios de pH foram ligeiramente maiores para as amostras de frango de granja. PPC não apresentou diferença significativa entre as amostras de frango de granja e frango caipira. O CRA foi melhor e maior para as amostras de frango caipira do que para as amostras de frango. Os valores médios de luminosidade (L*) ficaram dentro da normalidade, com valores ligeiramente superiores para frango de granja. Nas cromátides a* e b*, houve uma tendência de coloração mais avermelhada para as amostras de frango caipira. As diferenças encontradas para os tipos de produção podem ser explicadas principalmente pela diferença de idade ao abate, grau de atividade física, alimentação do animal, entre outras características que diferenciam um animal criado pelo sistema extensivo em relação ao sistema intensivo.

Palavras-chave: produção, frangos, qualidade, CRA, PPC.

1. Introduction

The domestic chicken, scientifically known as *Gallus gallus domesticus*, holds great significance in human societies and, together with other breeds of chicken, has been a species whose production has seen a considerable increase. Despite its importance, the complete origin and history of the genetic diversity of this significant domesticated species are only partially understood.

The Red junglefowl (*Gallus gallus*) is widely recognized as the maternal ancestor of the domestic chicken (Andersson and Purugganan, 2022; Charles, 2010). Mitochondrial DNA (mtDNA) evidence supports the existence of multiple domestication centers (Liu et al., 2006), with several subspecies of the Red junglefowl contributing to the genetic makeup of domestic chickens, except for *G. g. bankiva*, which is primarily found in Java, Bali, and Sumatra.

However, the *Gallus genus* includes three other wild species that may have played a role in the genetic background of the domestic chicken. In South Asia, the Grey junglefowl (*Gallus sonneratii*) inhabits Southwest India, while the Ceylon junglefowl (*Gallus lafayettii*) is

*e-mail: reitz@utfpr.edu.br
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found in Sri Lanka. In Southeast Asia, the Green junglefowl (*Gallus varius*) is endemic to Java and neighboring islands (Andersson and Purugganan, 2022). Hybridization between the Red and Grey junglefowl has been observed in their overlapping regions on the Indian subcontinent (Albuquerque et al., 2021). Hybridization between different Gallus species has also been reported in captivity (Nishibori et al., 2005). Notably, Morejohn successfully produced fertile F1 hybrids by crossing Red junglefowl with Grey junglefowl, followed by backcrossing with both species. The presence of Red junglefowl/domestic chicken mtDNA has been detected in captive Grey junglefowl (Andersson and Purugganan, 2022), and the yellow skin phenotype in domestic chickens likely resulted from the introgression of a chromosomal fragment from the Grey junglefowl (Albuquerque et al., 2021). Captive F1 hybrids between female domestic chickens and male Green junglefowl, known as Bekisar, are prevalent in Indonesia. They are valued for their distinctive plumage coloration and unique vocalizations (Albuquerque et al., 2021).

As mentioned, the current market for chicken meat, nationally and worldwide, has grown compared to the last three years. For 2024, the forecast is for a global chicken meat production of 103.3 million tons. Brazil surpassed China to become the world's second-largest producer in 2022 and continues to solidify its position. Brazil's record-high forecast is supported by strong foreign demand and moderating production costs, particularly lower feed prices (USDA, 2023).

When analyzing the free-range chicken meat market, as it is an emerging market, and in its vast majority informal, due to the more extended rearing period combined with the high cost of production, there is little documented data on the amount of consumption and production (Santos et al., 2020). However, Turra et al. (2015) mentioned that the demand for organic and artisanal products had grown significantly in recent years, which may directly affect the demand for free-range chicken meat, as it is popularly seen sometimes considered healthier product than chicken meat raised by traditional commercial methods.

Poultry meat corresponds to that obtained from domestic animals in confinement or not. The main characteristic of chicken meat, given to young animals of the species Gallus gallus domesticus, is white meat that is rich in proteins and low in lipids. But its color may vary depending on the animal's species, diet and degree of physical activity. Other characteristics, such as the percentage of macro and micronutrients, may vary due to the same factors, in addition to the animal's breed and age at slaughter (Oliveira et al., 2021; Gaya and Ferraz, 2006; Jumanee et al., 2022).

Meat quality in technological and functional terms can be characterized by physical-chemical measures, such as pH, texture, appearance, color, water retention capacity, and weight loss from cooking, among others, in addition to microbiological and sensory parameters. The most common abnormalities found in poultry meat can be identified by appearance and texture, mainly due to altered pH values, and coloration such as luminosity (L* value), among others, which may lead to the so-called DFD meat (dark, firm, dry - dark, hard and dry) and PSE (pale, soft, exudative - pale, soft and exudative), which generally have compromised functional and technological properties (Oliveira et al., 2021; Gaya and Ferraz, 2006).

Based on these considerations, the present study aimed to assess the quality of chicken breast meat (Pectoralis major) from both conventional and free-range chickens of different brands marketed in a municipality in the state of Paraná, Brazil. This involved determining the pH, instrumental color measurement (L*, a*, and b*), Water Retention Capacity (WRC), and Cooking Weight Loss (CWL).

2. Material and Methods

2.1. Raw material

The study was conducted with the breast cut (Pectoralis major) of free-range and conventional chickens. Conventional chickens (42 days old, weighing 2.5 and 3.5 kg) were purchased from supermarkets. In comparison, free-range chickens (90 days old, weighing 2.5 and 3.5 kg) were obtained directly from rural producers in a municipality in the state of Paraná, Brazil. All physicochemical analyses were carried out at the Meat Products Industrialization Laboratory of the Federal Technological University of Paraná (UTFPR) - Campo Mourão campus, with the breasts cooled after 48 hours of slaughter. One hundred and three animals were acquired from each producer/brand, meaning one hundred and three animals from each producer/brand A, B, and C, respectively, for conventional chickens purchased in the market (brand) and for free-range chickens purchased from rural producers, totaling 618 samples.

2.2. pH determination

The pH measurements were performed in triplicates with the aid of a Testo brand contact potentiometer, according to the methodology suggested by Olivo et al. (2001), with the point of incision of the electrode in the central part in the left part and the right part of the piece of meat.

2.3. Instrumental color measurement determination (L, a* and b*)*

The raw material was cut into 1.0 cm thick fillets weighing approximately 30 g. Measurements were performed with the MiniScan EZ colorimeter (HunterLab, MSEZ-0231). The results were expressed as L* (which represents the percentage of brightness, 0 = dark and 100 = light), a* (where -a* represents the green direction and +a* the red direction) and b* (where -b* represents the blue direction and +b* yellow direction).

2.4. Water retention capacity (WRC)

The water retention capacity was determined according to the methodology described by Araújo et al. (2022), using a 10 kg cylindrical weight, acrylic plates, screws fastened with butterflies, and Whatman n°.1 qualitative filter paper with 110 mm in diameter, previously dried in a desiccator saturated with KCl. Meat samples weighing 500±20mg were placed on filter paper between two acrylic plates secured with butterfly screws, and a 10kg cylindrical weight was placed on top of them for five minutes. The resulting meat sample was weighed, and, by difference, the amount of water lost was calculated.

2.5. Determination of weight loss by cooking (WLC)

The breast meat samples were cut into 1.0 cm thick fillets, weighing approximately 30 g. 2.0% table salt (NaCl), added, considered, and grilled at 200 ºC for 5 minutes on each fillet side. After grilling, the fillets were removed, cooled to 40ºC, and weighed again. The resulting meat sample was considered, and the percentage of weight lost during the cooking process was calculated by difference. The analysis was done in triplicate.

2.6. Statistical analysis

The mean values of all physicochemical analyses of pH, objective color, WRC, and WLC were submitted to ANOVA and Tukey's test to verify if there was a difference, at 5% significance, between the different breast meat samples from the animals studied, free-range chicken and chicken. PCA samples were performed with graph plotting using Statistica 12 and Origin 2020b software.

3. Results and Discussion

The variance analysis test was performed with a significance level of 5% for the physical-chemical analyses, and all models were significant (P<0.05) and had a good fit with R^2 above 90%. The results were analyzed according to Tukey's test, considering testing the hypotheses that all means of sample variables would be equal or at least one of the means would be different from the others. Physical-chemical tests of cooking weight loss (WLC), pH, water retention capacity (WRC), and instrumental color measurement (L*, a* and b*) were performed on free-range chicken breast samples from three different producers in the city of Campo Mourão/PR (A, B, C) and chicken of three other brands marketed in the city of Campo Mourão/PR (A, B, C), totaling 309 free-range chickens and 309 conventional chickens. The results of means and standard deviations are shown in Table 1.

Based on the data from Table 1, it is possible to verify that, overall, the samples of conventional chicken breast and free-range chicken did not show significant differences in cooking weight, with values ranging between 39.16 to 44.40% for conventional chicken and between 36.14 to 40.92% for free-range chicken. The values obtained in the WLC analyses were above the values cited by Oliveira et al. (2021), Droval et al. (2012), Figueira et al. (2014), and Komiyama et al. (2010), who obtained results between 18 and 29% for conventional chicken breast meat and an average of 30% for chicken breast meat raised in an alternative system (extensive systems such as free-range chickens), analyzed by Souza et al. (2012).

High results are explained by Venturini et al. (2007) that point to genetic, nutritional, age, and stress factors as influencers of water retention capacity and, consequently, weight loss by cooking, generally animals raised by the extensive system, called "free-ranges", have better water retention capacity and less weight loss due to cooking, as observed in the present study. On the other hand, Oliveira et al. (2021) claim that the degree of maturation of chicken meat can influence the same factors.

Regarding water retention capacity, there was a significant difference between the sample means, with higher values determined for free-range chickens (70.91 to 75.64%) and lower values for conventional chicken samples (61.77 to 66.27%). Even though weight loss due to cooking and water retention capacity are closely linked, the WRC analyses showed results within the expected range and cited in the literature (60 to 70%). Such effects can be explained by the factors influencing the WLC (Oliveira et al., 2021; Venturini et al., 2007).

The greater water retention capacity and a lower percentage of weight loss due to cooking in free-range chickens can be explained by the animals' slaughter age since animals reared in extensive systems do not have genetic alterations for weight gain. Therefore, they take longer to reach the ideal weight and size for slaughter, in addition to being animals with a higher degree of physical activity, which can increase the amount of water immobilized in muscle tissue (Oliveira et al., 2021; Souza et al., 2012).

Regarding the values determined for the pH analysis, the samples showed significant differences, with the highest value (5.81±0.02) for the free-range chicken breast sample for producer A and the lowest value (5.68±0.04)

Table 1. Physical-chemical analysis performed on conventional chicken and free-range chicken.

Samples	WLC (%)	pH	WRC (%)	Color parameters		
				L*	a*	b*
free-range chicken A	36.14^{b}±0.67	5.81^{a}±0.02	70.91^{ab}±1.00	50.27^{ab}±0.98	4.30^{ab}±0.58	28.38^{a}±1.92
free-range chicken B	40.92^{ab}±1.90	5.74^{ab}±0.01	75.26^{a}±1.64	49.31^{ab}±1.92	5.64^{a}±0.92	28.22^{a}±3.22
free-range chicken C	36.65^{b}±1.43	5.79^{ab}±0.02	75.64^{a}±1.59	50.60^{ab}±1.64	4.24^{ab}±0.66	22.31^{a}±1.16
conventional chicken A	39.16^{ab}±1.10	5.68^{b}±0.04	66.27^{bc}±1.26	53.90^{a}±0.67	2.93^{b}±0.54	25.19^{a}±1.66
conventional chicken B	44.27^{a}±0.76	5.85^{a}±0.03	61.77^{c}±1.16	52.66^{ab}±0.92	1.95^{b}±0.31	21.99^{a}±1.07
conventional chicken C	44.40^{a}±1.29	5.79^{ab}±0.04	65.61^{bc}±2.21	47.99^{b}±0.73	3.73^{ab}±0.63	25.90^{a}±2.04

Means in the same column, followed by different lowercase letters, differ by Tukey's test at a significance level of 5% for the control and each of the extracts analyzed individually.

for the conventional chicken breast sample for producer A. Making a comparison with the value of the L* parameter to verify the existence of PSE meat, it is not possible to confirm its presence in the studied samples because, according to (Droval et al., 2012), PSE is considered a chicken that presents L* value greater than 54 and a pH value less than 5.8, in none of the samples there was an L* value above 54. However, two samples had pH above 5.8 (5.81±0.02 and 5.85±0.02), not being able to affirm this negative linear correlation as meat samples of chicken with PSE characteristics. The difference found in the pH analyses can be directly related to the same factors that influence the WRA and WLC analyses, and, according to Figueira et al. (2014), an important factor to be taken into account is the age of slaughter of the animal, the older it is, the higher the pH of the meat. For Cruz et al. (2017) and Oliveira et al. (2021), birds reared in an alternative/extensive system are more resistant to antemortem stress, a major influencer in lowering pH in the post-mortem process.

There was a statistical difference between the studied samples regarding the color parameter for the a* chromatid. The highest value (5.64±0.92) for the free-range chicken breast from producer B and the lowest (1.95±0.31) was determined for the B brand conventional chicken breast sample. Still, the highest values for the a* chromatid were found for the free-range chicken breast samples (Table 1), where confirms that samples of meat from animals that have more excellent physical activity and older age groups, have higher levels of myoglobin, according to studies presented by Faria et al. (2009) and Jumanee et al. (2022), that is, they have a more positive color tending to a more reddish presentation, and this characteristic was observed in the free-range chicken samples from producers A, B and C.

For parameter b*, no significant differences were found between samples. However, the results found in this study differed from those found by Oliveira et al. (2021), which were mean values from 6.52 to 10.62. Souza et al. (2012) found mean values between 8.60 and 9.83 for chromatid b*, and this color parameter indicates a yellow color the more positive the result. According to Davoodi et al. (2022), free-range chickens can be characterized by different appearances due to the lower proportion of abdominal fat and more yellowish breast meat; they are also healthier and more nutritious due to the lower concentration of fat and higher protein content.

The previous results can be verified in Figure 1, where there is a PCA biplot graph considering the results of both analyses.

This figure shows the result of applying Principal Component Analysis (PCA), where it is observed that the PC1 x PC2 projection explained 74.90% of the variance. Factor 1 accounted for 50.40% of the variance, with free-range chicken breast samples projected with positive PC1 values based on WRC, a*, and b* values. Factor 2, with a variance of 24.50%, was responsible for discriminating the conventional chicken breast sample (positioned at the top) for WLC (%) and pH values and negatively related to L* values. However, in all evaluated samples, the luminosity parameter (L*) and pH value did not correlate with the presence of PSE meat.

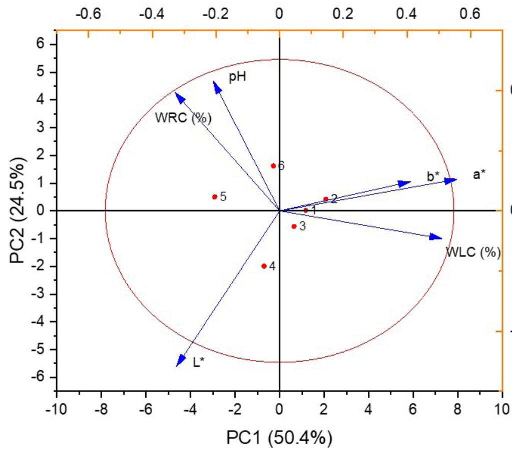

Figure 1. PCA biplot graph for physical-chemical analysis performed on conventional chicken and free-range chicken**.** Note: 1: free-range chicken A; 2: free-range chicken B; 3: free-range chicken C; 4: conventional chicken A; 5: conventional chicken B; 6: conventional chicken C.

4. Conclusion

It was observed that the free-range chickens obtained better results in terms of water retention capacity than the chickens created by the conventional system. Conventional chicken breast and free-range chicken samples did not show significant differences in cooking weight, with values ranging between 39.16 to 44.40% for conventional chicken and 36.14 to 40.92% for free-range chicken. In WRC, there was a significant difference between the sample means, with higher values determined for free-range chickens (70.91 to 75.64%) and lower values for conventional chicken samples (61.77 to 66.27%).

Regarding the values determined for the pH analysis, the samples showed significant differences, with the highest value (5.81±0.02) for the free-range chicken breast sample for producer A and the lowest value (5.68±0.04) for the conventional chicken breast sample for producer A. In the evaluated instrumental color measurement parameters, the average luminosity (L*) values were within the normal range, ranging from 49.31 to 50.60 for the free-range chickens and 47.99 to 53.90 for the conventional chickens. As well as the a* chromatid, there was a statistical difference between the studied samples. The highest value (5.64±0.92) for the free-range chicken breast from producer B and the lowest (1.95±0.31) was determined for the B brand conventional chicken breast sample. For parameter b*, no significant differences were found between samples.

The significant differences in the physicochemical parameters can be mainly explained by the disparity in the extensive breeding system, slaughter age, degree of physical activity, and animal feeding.

References

ALBUQUERQUE, M.F., GARCIA, A.M.L. and SILVA, I.H.L. 2021. Produção, custo e bem estar de galinha caipira da linhagem Embrapa 051 na agricultura familiar. *Agricultura Familiar:*

Pesquisa, Formação e Desenvolvimento, vol. 14, no. 2, pp. 121. http://doi.org/10.18542/raf.v14i2.9076.

ANDERSSON, L. and PURUGGANAN, M., 2022. Molecular genetic variation of animals and plants under domestication. *Proceedings of the National Academy of Sciences of the United States of America*, vol. 119, no. 30, pp. 2122150119. http://doi.org/10.1073/pnas.2122150119.

ARAÚJO, C.G.F., COSTA, M.G., DIFANTE, G.D.S., EMERENCIANO NETO, J.V., GURGEL, A.L.C., COSTA, C.M., DE ARAÚJO, I.M.M., SILVA, M.G.T. and MEDEIROS, M.C., 2022. Carcass characteristics, meat quality and composition of lambs finished in cultivated pastures. *Food Science and Technology*, vol. 42, pp. e71420. https://doi.org/10.1590/fst.71420.

CHARLES, D., 2010. *The variation of animals and plants under domestication*. Cambridge: Cambridge University Press. The variation of animals and plants under domestication, vol. 2. http://doi.org/10.1017/CBO9780511709517.

CRUZ, F.L., ESPÓSITO, M., NARDELLI, N.B.S., FASSANI, É.J., FARIA, P.B. and ESTEVES, C., 2017. Qualidade da carne de aves da raça rodhe island red criadas em sistema alternativo. *Ciência Animal Brasileira*, vol. 18, no. 1-16, pp. e-37834. http://doi.org/10.1590/1089-6891v18e-37834.

DAVOODI, P., EHSANI, A., VAEZ TORSHIZI, R. and MASOUDI, A.A., 2022. A meta-analysis comparing the composition and quality differences between chicken meats produced under the free-range and conventional systems. *World's Poultry Science Journal*, vol. 78, no. 2, pp. 353-375. http://doi.org/10.1080/00439339.2022.2008781.

DROVAL, A.A., BENASSI, V.T., ROSSA, A., PRUDENCIO, S.H., PAIÃO, F.G. and SHIMOKOMAKI, M., 2012. Consumer attitudes and preferences regarding pale, soft, and exudative broiler breast meat. *Journal of Applied Poultry Research*, vol. 21, no. 3, pp. 502-507. http://doi.org/10.3382/japr.2011-00392.

FARIA, P.B., BRESSAN, M.C., SOUZA, X.R., RODRIGUES, É.C., CARDOSO, G.P. and GAMA, L.T., 2009. Composição proximal e qualidade da carne de frangos das linhagens Paraíso Pedrês e Pescoço Pelado. *Revista Brasileira de Zootecnia*, vol. 38, no. 12, pp. 2455-2464. http://doi.org/10.1590/S1516-35982009001200023.

FIGUEIRA, S.V., NASCIMENTO, G.M., MOTA, B.P., LEONÍDIO, A.R.A. and ANDRADE, T.S., 2014. Bem - Estar Animal Aplicado a frangos de corte. *Enciclopédia Biosfera*, vol. 10, no. 18, pp. 643.

GAYA, L.G. and FERRAZ, J.B.S., 2006. Aspectos genético-quantitativos da qualidade da carne em frangos. *Ciência Rural*, vol. 36, no. 1, pp. 349-356. http://doi.org/10.1590/S0103-84782006000100058.

JUMANEE, S., CHAOSAP, C., SIVAPIRUNTHEP, P., KLOMPANYA, A., SETAKUL, J. and SITTHIGRIPONG, R., 2022. Influence of age on the incidence of wooden breast and white striping, carcass composition, meat physicochemical property, texture profile, and chemical composition of broiler chickens. *Agricultural Technology (Thailand)*, vol. 18, no. 1, pp. 193-204.

KOMIYAMA, C.M., MENDES, A.A., SANFELICE, C., CAÑIZARES, M.C., ROÇA, R.O., TAKAHASHI, S.E., RODRIGUES, L., CAÑIZARES, G.I.L., PAZ, I.C.L.A. and CARDOSO, K.F.G., 2010. Qualidade físico-química e sensorial da carne de peito de matrizes pesadas de descarte. *Ciência Rural*, vol. 40, no. 7, pp. 1623-1629. http://doi.org/10.1590/S0103-84782010000700022.

LIU, Y.P., WU, G.S., YAO, Y.G., MIAO, Y.W., LUIKART, G., BAIG, M., BEJA-PEREIRA, A., DING, Z.L., PALANICHAMY, M.G. and ZHANG, Y.P., 2006. Multiple maternal origins of chickens: out of the Asian jungles. *Molecular Phylogenetics and Evolution*, vol. 38, no. 1, pp. 12-19. http://doi.org/10.1016/j.ympev.2005.09.014. PMid:16275023.

NISHIBORI, M., SHIMOGIRI, T., HAYASHI, T. and YASUE, H., 2005. Molecular evidence for hybridization of species in the genus Gallus except for Gallus varius. *Animal Genetics*, vol. 36, no. 5, pp. 367-375. http://doi.org/10.1111/j.1365-2052.2005.01318.x. PMid:16167978.

OLIVEIRA, R.F., DE MELLO, J.L.M., FERRARI, F.B., CAVALCANTI, E.N.F., DE SOUZA, R.A., PEREIRA, M.R., GIAMPIETRO-GANECO, A., VILLEGAS-CAYLLAHUA, E.A., FIDELIS, H.A., FÁVERO, M.S., AMOROSO, L., DE SOUZA, P.A. and BORBA, H., 2021. Physical, chemical and histological characterization of pectoralis major muscle of broilers affected by wooden breast myopathy. *Animals (Basel)*, vol. 11, no. 3, pp. 596. http://doi.org/10.3390/ani11030596. PMid:33668299.

OLIVO, R., SOARES, A.L., IDA, E.I. and SHIMOKOMAKI, M., 2001. Dietary vitamin E inhibits poultry PSE and improves meat functional properties. *Journal of Food Biochemistry*, vol. 25, no. 4, pp. 271-283. http://doi.org/10.1111/j.1745-4514.2001.tb00740.x.

SANTOS, L.I., SANTOS, A.O., AUGUSTO, E.E., SANTOS GAZOLI, M.R. and PANDOLFI, M.A.C., 2020. A evolução do mercado do frango caipira no Brasil. *Revista Interface Tecnológica*, vol. 17, no. 2, pp. 567-577. http://doi.org/10.31510/infa.v17i2.943.

SOUZA, X.R., FARIA, P.B. and BRESSAN, M.C., 2012. Qualidade da carne de frangos caipiras abatidos em diferentes idades. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, vol. 64, no. 2, pp. 479-487. http://doi.org/10.1590/S0102-09352012000200031.

TURRA, C., GHISI, F., FREITAS VIAN, C., MOREIRA, C. and FERRAREZ, A., 2015. The Brazilian consumer's profile and perceptions of organic foods: a review. *Global Advanced Research Journal of Agricultural Science*, vol. 4, pp. 775-783.

UNITED STATES DEPARTMENT OF AGRICULTURE - USDA, 2023. *Livestock and poultry: world markets and trade* [online]. USA: United States Department of Agriculture [viewed 20 July 2023]. Available from: https://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf

VENTURINI, K., SARCINELLI, M. and DA SILVA, L.C., 2007 [viewed 20 July 2023]. Características da carne de frango. *Boletim Técnico* [online], vol. 1, pp. 1-7. Available from: http://www.agais.com/telomc/b01307_caracteristicas_carnefrango.pdf