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Physicochemical and sensory properties of restructured ham from caiman, chicken and rabbit meat

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Abstract – The objective of this work was to evaluate the proximate composition, instrumental color, pH, water activity, texture, and sensory acceptance of restructured ham prepared with Pantanal caiman (*Caiman yacare*), chicken (*Gallus gallus domesticus*), and rabbit (*Oryctolagus cuniculus*) meat. Physicochemical and instrumental data were subjected to the analysis of variance at a 5% significance level, and sensory data were evaluated using the Friedman test. Significant differences were observed for crude protein, total lipids, ash, energy value, instrumental color, water activity, and sensory acceptance. However, moisture, carbohydrate content, pH, and texture profile parameters did not differ significantly among treatments. Caiman ham showed the highest crude protein content (17.51%) and the lowest total lipid content (1.41%), whereas rabbit ham presented the highest total lipid content (6.61%), lowest crude protein content (13.61%), highest energy value (116.39 kcal 100 g^{-1}), and highest consumer acceptance. Moreover, chicken ham exhibited the highest ash content (9.52%) and highest lightness and yellowness values, while caiman ham presented the highest redness value. These results show the potential of rabbit meat for the production of restructured ham with a high consumer acceptance.

Index terms: *Caiman yacare*, *Gallus gallus domesticus*, *Oryctolagus cuniculus*, consumer acceptance, value-added products.

Propriedades físico-químicas e sensoriais de presunto reestruturado de carne de jacaré, frango e coelho

Resumo – O objetivo deste trabalho foi avaliar a composição centesimal, a cor instrumental, o pH, a atividade de água, a textura e a aceitação sensorial de presunto reestruturado elaborado com carne de jacaré-do-pantanal (*Caiman yacare*), frango (*Gallus gallus domesticus*) e coelho (*Oryctolagus cuniculus*). Os dados físico-químicos e intrumentais foram submetidos à análise de variância a 5% de significância, e os dados sensoriais foram analisados pelo teste de Friedman. Foram observadas diferenças significativas para proteína bruta, lipídios totais, cinzas, valor energético, cor instrumental, atividade de água e aceitação sensorial. No entanto, umidade, carboidratos, pH e os parâmetros de textura não diferiram significativamente entre os tratamentos. O presunto de jacaré apresentou o maior teor de proteína bruta (17,51%) e o menor teor de lipídios totais (1,41%), enquanto o de coelho teve o maior teor de lipídios totais (6,61%), o menor teor de proteína bruta (13,61%), o maior valor energético (116,39 kcal 100 g^{-1}) e a maior aceitação pelos consumidores. O presunto de frango exibiu o maior teor de cinzas (9,52%) e os maiores valores

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de luminosidade e amarelecimento, enquanto o presunto de jacaré apresentou a maior intensidade de vermelho. Esses resultados mostram o potencial da carne de coelho para a elaboração de presuntos reestruturados com elevada aceitação pelos consumidores.

Termos para indexação: *Caiman yacare*, *Gallus gallus domesticus*, *Oryctolagus cuniculus*, aceitação do consumidor, produtos com valor agregado.

Introduction

Meat is widely recognized for its high nutritional value, being an important source of proteins with high biological value, iron, zinc, and B-complex vitamins, essential nutrients that are difficult to obtain in adequate amounts from plant-based foods (Kavanaugh et al., 2025). In this context, diversifying animal protein sources and developing innovative processed meat products have gained prominence as key strategies to expand product portfolios, add value to alternative raw materials, and satisfy consumer interest in differentiated foods with desirable nutritional and sensory characteristics (Monteiro et al., 2026).

Processed meat products undergo physical and chemical treatments that partially modify the properties of fresh meat, conferring desirable organoleptic attributes —such as color, flavor, and aroma— without significantly compromising their nutritional value (Gómez et al., 2020; Fasulkova et al., 2024). Beyond extending shelf life, processing adds value to cuts with lower commercial acceptance and promotes the integration of new raw materials into the consumer market (Pomianowski & Sobotka, 2024).

Among the species with potential for use in the production of processed meat products, the Pantanal caiman (*Caiman yacare*), European rabbit (*Oryctolagus cuniculus*), and chicken (*Gallus gallus domesticus*) stand out, because their meats present distinct yet complementary nutritional and sensory characteristics. Caiman meat is characterized by low fat and cholesterol content, high digestibility, and high biological value, making it a noble and exotic protein alternative (Fasulkova et al., 2024). However, its commercial availability remains limited due to management and processing challenges, with distribution restricted to directed toward specialized restaurants (Rebello et al., 2022; Taques et al., 2022).

Rabbit meat stands out for its low fat and cholesterol content, high protein concentration, and favorable unsaturated fatty acid profile, characteristics that make it a healthy and versatile raw material for meat product development (Siddiqui et al., 2023). Chicken meat is widely consumed and economically accessible; it not only presents mild flavor and high sensory acceptance, but also serves as a reference standard in product development research (Baéza et al., 2022).

Utilizing meat from these three species allows the exploration of distinct flavor profiles, textures, and compositions, contributing to the development of differentiated and technologically feasible products. Furthermore, the formulation of restructured ham-type products from alternative meats represents a strategy to diversify the meat industry portfolio, target niche markets, and add value to unconventional proteins (Galenko et al., 2021).

The objective of this work was to evaluate the proximate composition, instrumental color, pH, water activity, texture, and sensory acceptance of restructured ham prepared with Pantanal caiman, chicken, and rabbit meat.

Materials and Methods

The study was conducted at the Universidade Estadual de Maringá (UEM), in the municipality of Maringá, Paraná, Brazil. The manufacturing of the restructured ham-type products was carried out at the Food Production Technology Laboratory of UEM.

To manufacture of the ham-type products, caiman meat trimmings were obtained from Caimasul Farm, located in the municipality of Corumbá, Mato Grosso do Sul, Brazil. Chicken breast meat was purchased from a local supermarket in Maringá, while rabbit meat was obtained from frozen whole rabbit carcasses donated by the Fazenda Experimental de Iguatemi, located in the municipality of Maringá, Paraná, Brazil. All meats were received frozen and kept under frozen storage until processing. Prior to product preparation, the meat samples were thawed under refrigeration for 12 hours, after which the rabbit carcasses were manually deboned, and the meat was separated to use in the formulations.

Subsequently, each meat was ground separately using a conventional meat grinder fitted with an 8 mm

diameter grinding plate and then weighed for product formulation.

The formulations were prepared using caiman trimmings, chicken meat, or rabbit meat according to the respective treatment, combined with starch, transglutaminase, sodium erythorbate, neutral seasoning, sugar, salt, and water. Table 1 presents the ingredient composition of each formulation.

The ground meat was blended with the ingredients in a mixer for 10 minutes until a homogeneous batter formed. The mixture was then transferred to plastics casings suitable for ham processing, tied with string and placed into a ham moldd for cooking.

The mold was subsequently sealed and placed in a water bath at 80°C for 2 hours. It was then removed and allowed to rest for 30 minutes to cool down before going under refrigeration for 24 hours.

Thereafter, the ham-type products were removed from the molds, and sampled for laboratory analyses. The remaining products were kept under refrigeration until sensory evaluation was performed.

Chemical composition analyses were performed at UEM's Food Analysis and Animal Nutrition Laboratory. Moisture and ash contents according to the methods described by the Association of Official Analytical Chemists (AOAC) (Horwitz, 2005). Crude protein content was measured using the semi-micro Kjeldahl method (Silva & Queiroz, 2006), and total lipids were quantified following the methodology described by Bligh & Dyer (1959). Carbohydrate content was calculated by difference, subtracting the sum of moisture, crude protein, total lipids, and ash percentages from 100%. Finally, the energy value was calculated according to Souci et al. (2000) using the following formula: Energy value (kcal g^{-1}) = (Crude protein × 4) + (Total lipids × 9) + (Carbohydrates × 4).

Table 1. Ingredients used in the formulation of restructured ham-type products.

Components	Caiman	Chicken	Rabbit
Meat (g)	1,000.00	1,000.00	1,000.00
Starch (g)	28.60	28.60	28.60
Transglutaminase enzyme (g)	10.00	10.00	10.00
Sodium erythorbate (g)	3.57	3.57	3.57
Neutral seasoning (g)	14.30	14.30	14.30
Sugar (g)	2.85	2.85	2.85
Salt (g)	20.00	20.00	20.00
Water (mL)	428.60	428.60	428.60

Texture profile analysis was conducted using a Brookfield texture analyzer according to the methodology described by Serra et al. (2005). Cylindrical samples measuring 2.2 cm in height and 1.5 cm in diameter were evaluated at approximately 20°C using a double-compression cycle to determine hardness (g), gumminess (g), springiness (mm), chewiness (mJ), and cohesiveness.

Sensory evaluation was conducted at UEM, with 110 untrained panelists, including students, staff, and other members of the university community. Each participant received one sample from each treatment, accompanied by a water cracker and water, which they were instructed to consume between samples to prevent carryover effects.

Consumer acceptance across color, aroma, texture, flavor, and overall impression was evaluated using an affective acceptance test (Damásio & Silva. 1996), with a 9-point hedonic scale ranging from 1 ("extremely disliked") to 9 ("extremely liked"). Purchase intention was subsequently assessed on a 5-point scale ranging from 1 ("certainly would not buy") to 5 ("certainly would buy"), following the procedures described by Meilgaard et al. (1991) and Pietrasik et al. (2020). FInally, the Acceptability Index (AI) was calculated as proposed by Dutcosky (2013): AI (%) = (mean score / highest score on the hedonic scale) × 100.

Physicochemical and instrumental data were subjected to analysis of variance (ANOVA), and treatment means were compared using Tukey's test at a 5% significance level ($p<0.05$) when significant differences were observed. Sensory data were analyzed using Friedman's test followed by Wilcoxon's signed-rank test with Bonferroni correction for pairwise comparisons when significant differences were detected. All analyses were performed using R software version 4.5.1 (R Core Team, 2025).

Results and Discussion

The proximate composition and mean energy values of the restructured ham-type products are shown in Table 2. Significant differences were observed for crude protein ($p = 0.0389$), total lipids ($p = 0.0043$), ash ($p = 0.0001$), and energy value ($p = 0.0001$), whereas

moisture (p = 0.0604) and carbohydrate (p = 0.8559) contents did not differ among products.

Moisture content was similar among the restructured ham-type products, measuring 70.57% for chicken, 69.86% for rabbit, and 71.76% for caiman (p = 0.0604). This similarity can be associated to the equal amount of water added to the formulations. Taques et al. (2022), evaluated restructured products prepared with 60% mechanically separated meat from *Caiman yacare*, and reported a moisture content of 46.86%, lower than that observed in the present study. However, mechanically separated meat is obtained by mechanically recovering muscle tissue from carcasses and differs from whole meat in its physicochemical characteristics (Paiva et al., 2024). Consequently, the differences observed between studies are likely related to the raw material used and the product formulation.

The restructured ham-type product prepared with rabbit meat showed the highest total lipid content at 6.61% compared with 2.95% for the chicken and 1.41% for caiman (p = 0.0043). This result is caused by the use of whole rabbit carcasses, which included cuts with higher levels of subcutaneous and intramuscular fat, thereby increasing the total lipid content. Although rabbit meat is considered lean, its fat content can vary depending on the cut and portion selection (Cullere et al., 2022). More broadly, reported chemical compositions for rabbit meat is highly variable due to differences in cuts, as well as factors related to diet, animal age, and slaughter weight (Barcellos et al., 2011).

These authors reported that higher intramuscular fat content is associated with higher slaughter age, ranging from 2.2 to 4.6%. Although true intramuscular fat cannot be easily trimmed, major fat deposits – found in smaller proportions in the scapular region and larger proportions in the perirenal region – do not mix with muscle fibers and can be discarded during carcass processing (Kavanaugh et al., 2025). Furthermore, Szendrő et al. (1999), observed that for rabbits slaughtered at 2.2 to 3.5 kg, protein, fat, and moisture contents of the Biceps femoris muscle ranged from 21.9 to 22.5, 2.5 to 4.11, and 73.2 to 74.6%, respectively.

Conversely, the higher lipid content in the rabbit-based product was driven by residual carcass fat remaining after deboning, along with intramuscular fat. In the case of rabbit meat, the presence of residual carcass fat after deboning and intramuscular fat contributes to the higher lipid content observed. Furthermore, rabbit meat may retain more fat during emulsion due to its protein composition and lipid distribution within muscle fibers (Soares et al., 2018; Monteiro et al., 2026).

Crude protein content varied significantly among the different products (p = 0.0389), with the highest value found in the caiman ham-type product (17.51%) and lowest in the rabbit product (13.61%). Caiman meat is recognized for its high protein content and low fat, typical characteristics of exotic meats from semi-aquatic animals (Souza et al., 2022). The lower protein content in the rabbit product may be related to the use of the whole carcass, which includes different types of cuts with lower protein content. Moreover, rabbit meat generally contains 21.1 to 22.1% crude protein regardless of slaughter weight (Kumar et al., 2025).

Ash content also showed significant differences (p = 0.0001), with the chicken product exhibiting a higher value (9.52%) than the rabbit (9.10%) and caiman (8.66%) products. This result indicates differences in mineral composition among the evaluated meat sources.

Table 2. Means for proximate composition of restructured ham-type products prepared with chicken (*Gallus gallus domesticus*), rabbit (*Oryctolagus cuniculus*), and caiman (*Caiman yacare*) trimmings[(1)].

Proximate composition	Chicken	Rabbit	Caiman	p-value
Moisture (%)	70.57	69.86	71.76	0.0604
Crude protein (%)	16.37ab	13.61b	17.51a	0.0389
Total lipids (%)	2.95b	6.61a	1.41b	0.0043
Ash (%)	9.52a	9.10b	8.66b	0.0001
Carbohydrates (%)	0.59	0.61	0.65	0.8559
Energy value (kcal 100 g^{-1})	94.39b	116.39a	85.33c	0.0001

[(1)]Means followed by different letters, in the line, significantly differ to from each other by Tukey's test, at 5% probability.

Similarly, Yaranoğlu et al. (2023) reported significant interspecies variations in mineral composition when comparing beef, lamb, chicken, and rabbit meat.

Energy values differed significantly among products ($p = 0.0001$). The rabbit meat ham-type product showed the highest caloric value of 116.39 kcal 100 g^{-1}, followed by the chicken and caiman products at 94.39 kcal 100 g^{-1} and 85.33 kcal 100 g^{-1}, respectively. These differences are mainly explained by the higher lipid content observed in the rabbit formulation, as lipids contribute more energy per gram than proteins and carbohydrates.

Regarding the texture analysis for the restructured ham-type products, no significant differences were observed for hardness deformation ($p = 0.7722$), cohesiveness ($p = 0.6544$), springiness ($p = 0.2047$), gumminess ($p = 0.8646$), or chewiness ($p = 0.9186$) as shown in Table 3. In the literature, texture characteristics of rabbit meat may vary in cohesiveness, springiness, and chewiness depending on the breed and sex (Siddiqui et al., 2023) , and higher total lipid levels are known to influence texture and juiciness (Gómez et al., 2020). Additionally, raw rabbit meat is characterized as fibrous, firm, and relatively dry (Mo et al., 2023). Nevertheless, despite the significantly higher lipid content in the rabbit-based formulation, instrumental texture parameters remained uniform across all treatments.

The uniform values for hardness deformation, cohesiveness, springiness, gumminess, and chewiness indicate that incorporating chicken, rabbit, and caiman meat did not compromise the textural characteristics of the restructured ham-type products. The standardized formulation and processing conditions contributed to the development of products with similar texture, as processing conditions and functional ingredients play an important role in the formation of restructured meat products (Ren et al., 2024).

Instrumental color analysis revealed that meat type affected lightness (L*), redness (a*), yellowness (b*). Specifically, the L* value was higher in the chicken ham than in the rabbit and caiman products ($p<0.0001$). Chicken meat contains lower myoglobin and a predominance of type IIb glycolytic muscle fibers, resulting in a naturally lighter color (Mo et al., 2023). Conversely, higher myoglobin levels in rabbit and caiman meats produced darker products.

The a* value was the highest in the caiman ham, followed by the rabbit and chicken products ($p<0.0001$). This result is consistent with the greater concentration of heme pigments in caiman meat. Additionally, Patarata et al. (2022) observed that nitrite contributes to

Table 3. Means and standard deviations of texture analysis variables of restructured ham-type products prepared with chicken (*Gallus gallus domesticus*), rabbit (*Oryctolagus cuniculus*), and caiman (*Caiman yacare*) trimmings.

Variable	Chicken	Rabbit	Caiman	p-value
Hardness deformation (mm)	8.20 ± 2.12	7.25 ± 0.41	7.27 ± 2.45	0.7722
Cohesiveness	0.23 ± 0.13	0.16 ± 0.02	0.17 ± 0.11	0.6544
Springiness (mm)	9.33 ± 0.42	9.05 ± 0.35	7.78 ± 1.70	0.2047
Gumminess (g)	262.67 ± 139.75	212.00 ± 22.72	240.50 ± 156.27	0.8646
Chewiness (mJ)	24.33 ± 14.00	20.07 ± 0.47	22.70 ± 20.22	0.9186

Table 4. Means and standard deviations for colorimetric variables, pH, and water activity of restructured ham-type products prepared with chicken (*Gallus gallus domesticus*), rabbit (*Oryctolagus cuniculus*), and caiman (*Caiman yacare*) trimmings[(1)].

Variable	Chicken	Rabbit	Caiman	p-value
L* (lightness)	69.83 ± 1.45a	46.63 ± 1.21b	47.17 ± 3.13b	<0.0001
a* (redness)	13.81 ± 0.87c	15.34 ± 0.44b	18.45 ± 1.30a	<0.0001
b* (yellowness)	28.38 ± 0.44a	21.32 ± 1.03b	22.25 ± 1.49b	<0.0001
pH	6.22 ± 0.03	6.25 ± 0.06	6.22 ± 0.04	0.4475
Water activity	0.9517 ± 0.0019c	0.9520 ± 0.0009b	0.9537 ± 0.0014a	<0.0001

[(1)]Means followed by different letters, in the line, significantly differ to from each other by Tukey's test, at 5% probability.

the development of the characteristic red color of cured meat products, increasing consumer acceptability.

Chicken ham also showed the highest b* values ($p<0.0001$). This characteristic may be associated with the deposition of dietary carotenoids, particularly xanthophylls, which accumulate in muscle tissue and in the lipid fraction (Kume et al., 2025). As no colorants were added to the formulations, the observed color reflects the intrinsic characteristics of the raw materials and the effects of processing.

No significant differences in pH were observed among the products, with values ranging from 6.22 to 6.25 ($p = 0.4475$). These values are within the range reported for cooked meat products and indicate that replacing the meat source did not affect this characteristic. Meat pH is an important quality attribute because it influences technological properties, such as water-holding capacity, color, tenderness, and consumer acceptance (Behrens et al., 2026).

Water activity differed among treatments ($p<0.0001$), as the highest value observed was in the caiman ham, followed by the rabbit and chicken products. Despite the statistical difference, water activity values were very similar, ranging from 0.9517 to 0.9537. Similar values have been reported for cooked meat products, in which water activity is an important factor affecting product quality and shelf life (Lemos Junior et al., 2024).

Sensory evaluation revealed significant differences across all evaluated parameters: color ($p<0.001$), aroma ($p = 0.049$), texture ($p<0.001$), flavor ($p<0.001$), overall impression ($p<0.001$), and purchase intention ($p<0.001$), as detailed in Table 5. The rabbit ham received the highest scores for all evaluated attributes. For color, it obtained a mean score of 7.30, which was higher than the caiman and chicken products at 6.08 and 4.75, respectively. Regarding aroma, there were no significant differences between products, as the rabbit ham showed higher acceptance, the caiman ham presented intermediate acceptance, and the chicken ham achieved the lowest acceptance. For texture, flavor, overall impression, and purchase intention, the rabbit ham also received higher scores than the chicken and caiman products, which did not significantly differ from each other.

The acceptability indices confirmed the sensory evaluation outcomes. The rabbit ham presented AIs of 81.11, 78.89, 82.78, 78.35, and 79.00% for color, texture, flavor, overall impression, and purchase intention, respectively, (Figure 1). For aroma, the AI was 69.44%, a value approaching the 70% threshold required for a product to be considered well accepted by consumers (Dutcosky, 2013). In contrast, chicken and caiman hams presented AI below 70% for all evaluated attributes.

The superior consumer acceptance of the rabbit ham may be related to its higher lipid content. Fat contributes to sensory attributes such as juiciness, texture, and flavor, directly influencing consumer acceptance of processed meat products (Gómez et al., 2020). In the present study, rabbit ham presented the highest lipid content, and received the highest scores for texture, flavor, and overall impression, suggesting that lipid content may have positively influenced consumer perception.

The lower acceptance of chicken and caiman hams may be related to the fact that ham is traditionally produced from pork, which may influence consumer

Table 5. Means for the sensory acceptance scores of restructured ham-type products prepared with chicken (*Gallus gallus domesticus*), rabbit (*Oryctolagus cuniculus*), and caiman (*Caiman yacare*) meat[(1)].

Sensory attribute	Chicken	Rabbit	Caiman	p-value (Friedman)
Color	4.75c	7.30a	6.08b	< 0.001
Aroma	5.38b	6.25a	5.85ab	0.049
Texture	5.75b	7.10a	5.55b	< 0.001
Flavor	5.68b	7.45a	5.53b	< 0.001
Overall impression	4.99b	7.05a	5.56b	< 0.001
Purchase intention	2.83b	3.95a	3.03b	< 0.001

[(1)]Means followed by different letters, in the lines, significantly differ to from each other by Wilcoxon's signed-rank test with Bonferroni correction ($p<0.05$) performed after Friedman's test.

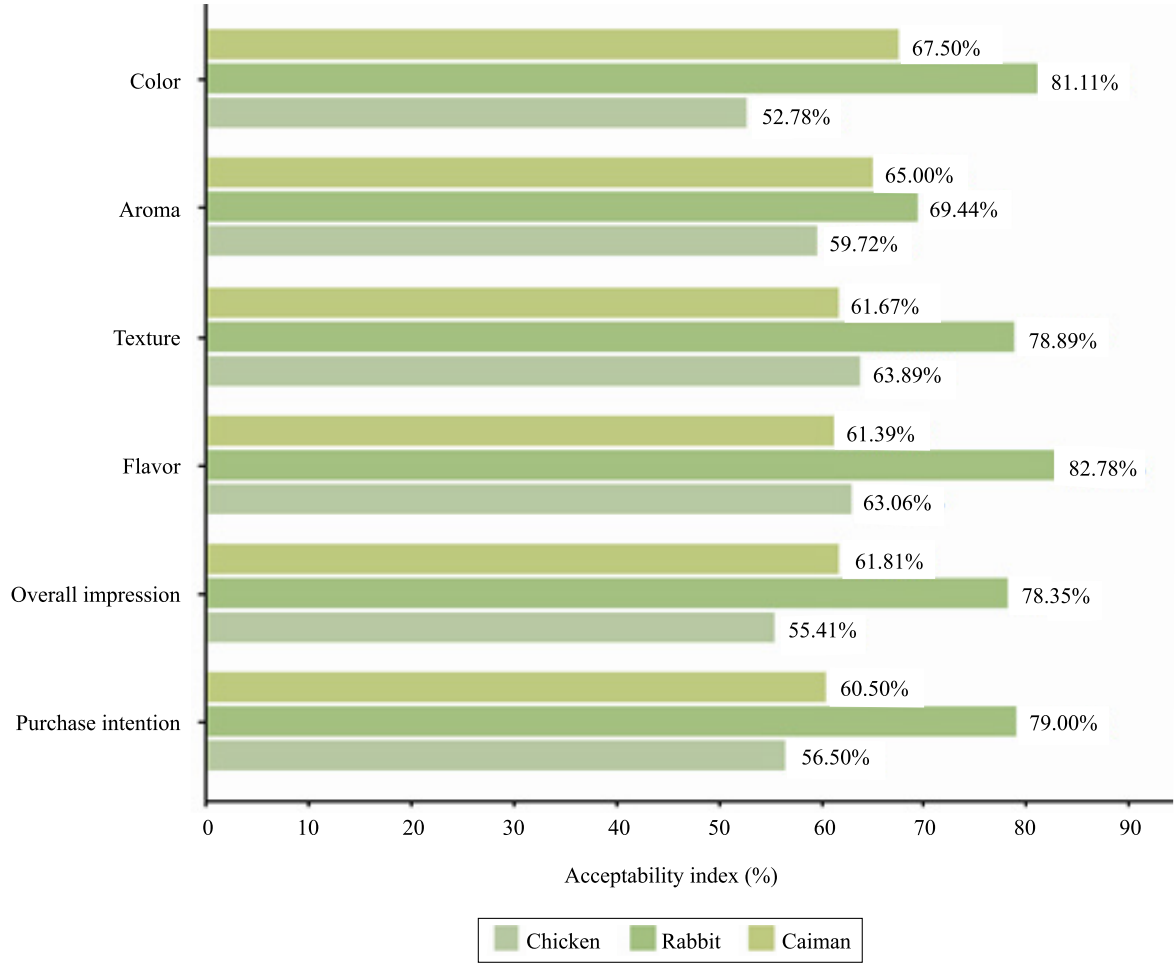

Figure 1. Acceptability index for the sensory attributes of restructured ham-type products prepared with chicken (*Gallus gallus domesticus*), rabbit (*Oryctolagus cuniculus*), and caiman (*Caiman yacare*) meat.

expectations regarding color, flavor, and texture of this type of product. Barcellos et al. (2011) highlighted the strong consumer preference for pork in Brazil, which may contribute to greater familiarity with pork-based processed products. However, Fernandes et al. (2013) reported good consumer acceptance of burgers prepared from Pantanal caiman trimmings, suggesting that consumer acceptance of caiman meat may vary according to the type of processed product.

Conclusions

1. The chicken (*Gallus gallus domesticus*), rabbit (*Oryctolagus cuniculus*), and caiman (*Caiman yacare*) meat type influences physicochemical characteristics and sensory acceptance of restructured ham products.

2. Rabbit ham shows the highest consumer acceptance and energy value among the evaluated formulations.

3. Caiman ham presents higher protein content and lower lipid content than other formulations.

4. Texture profile variables do not significantly differ among formulations, indicating similar technological performance regardless of meat source.

5. Rabbit and caiman meat are viable alternatives for the production of value-added restructured ham products.

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Data available upon request: research data are only available upon reasonable request to the corresponding author.

Declaration of use of AI technologies

During the preparation of this work, the authors used Consensus and SciSpace Copilot (SciBot) platforms in order to identify and retrieve scientific literature relevant and ChatGPT (OpenAI) was used to assist with grammar revision, text organization, writing coherence, and language editing. After this use, the authors reviewed and edited the content as needed and takes full responsibility for it.

Declaration of Consent to Participate

The sensory evaluation conducted in this work was approved by the Research Ethics Committee of the State University of Maringá, under approval number n°4000170615. All participants voluntarily participated and provided informed consent prior to the sensory analysis.

Conflict of interest statement

The authors declare that they have no known financial or non-financial conflicts of interest that could have appeared to influence the work reported in this manuscript.

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