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Profile of Nitrogenous compounds and Bacterial proliferation in Rabbit meat stored cold with three types of packaging

Perfil de compuestos nitrogenados y proliferación bacteriana en carne de conejo almacenada en frio con tres tipos de empaques

Technical note

Verónica Reséndiz-Cruz[1], Esperanza García-López[2], Jacinto Efrén Ramírez-Bribiesca[3], David Hernández-Sánchez[3], Isabel Guerrero-Legarreta[4], Daniel Mota-Rojas[5], Juan Edrei Sánchez-Torres[6] and Rosy Gabriela Cruz-Monterrosa[1]*

*[1]Universidad Autónoma Metropolitana, Departamento de Ciencias de los Alimentos. Unidad Lerma, Lerma de Villada, México. [2]Universidad Nacional Autónoma de México, Facultad de Estudios Superiores Cuautitlán, Laboratorio de Medicina Preventiva. Cuautitlán Izcalli, México. [3]Colegio de Postgraduados, Programa de Ganadería. Montecillo, México. [4]Universidad Autónoma Metropolitana, Departamento de Biotecnología. Unidad Iztapalapa, México. [5]Universidad Autónoma Metropolitana, Medicina Veterinaria y Zootecnia. Unidad Xochimilco, México. [6]Universidad Autónoma del Estado de México, Facultad de Medicina Veterinaria y Zootecnia. Toluca, México. *Email: r.cruz@correo.ler.uam.mx*

ABSTRACT

Meat is an excellent medium for bacterial growth due to its high water and nutrient content. The nitrogenous compounds (NC) are derived through decarboxylation of amino acids due to microbial enzymes. The objective of this study was to evaluate the concentration of 3 NC and the proliferation of some microorganisms in rabbit meat with three treatments (T), classified by three types of packaging for 21 days (d) in rabbit meat stored cold. The meat samples were obtained of the *Longissimus thoracis et lumborum* muscle. Each sample was divided and two groups were formed. The first group was used to measure the physicochemical characteristics of the meat, and the second group was used to quantify NC and bacterial isolation. The pH in the meat decreased from 0 to 21 d in the three T. The brightness (L*) decreased (P<0.05), while the variables a* and b* increased (P<0.05) to 21 d for all groups. Histamine and cadaverine remained low and were similar in the three T (P>0.05). Putrescine (PU) increased (P<0.05) from 7 to 21 d in the Control-Plastic (CP) and Semi-permeable plastic film (SP) groups *vs.* Vacuum packing (VP). The *Enterobacteriaceae* remained constant throughout the experimental period in the three T, compared to the aerobic mesophilic, which was higher (P<0.05) until 21 d of the evaluation in CP and SP. The type of packaging and cooling time influenced the concentration of NC. The VP had the lowest level of PU and mesophilic bacteria until 21 d of storage.

Key words: Bacteria contamination; meat; packaging; rabbit

RESUMEN

La carne es un excelente medio para el crecimiento bacteriano debido a su alto contenido de agua y nutrientes. Los compuestos nitrogenados (NC) se obtienen a través de la descarboxilación de aminoácidos debido a las enzimas bacterianas. El objetivo de este estudio fue evaluar la concentración de 3 NC y la proliferación de algunos microorganismos en carne de conejo con tres tratamientos (T), clasificados por los tipos de empaques almacenada en frío durante 21 días (d). Las muestras de carne se obtuvieron del músculo *Longissimus thoracis et lumborum*. Cada muestra se dividió y se formaron dos grupos. El primer grupo se utilizó para medir las características fisicoquímicas de la carne, y el segundo grupo se utilizó para cuantificar los CN y el aislamiento bacteriano. El pH en la carne disminuyó de 0 a 21 d en los tres T. La luminosidad (L*) disminuyó (P<0,05), mientras que las variables a* y b* aumentaron (P<0,05) a los 21 d para todos los T. La histamina y cadaverina se mantuvieron bajas y fueron similares en los tres T (P>0,05). La putrecina (PU) aumentó (P<0,05) de 7 a 21 d en los grupos Control-plástico (CP) y Película plástica semipermeable (SP) vs. Empaque al vacío (VP). Las bacterias *Enterobacteraceae* se mantuvieron constantes durante todo el período experimental en los tres T, en comparación con las bacterias aerobias mesófilas, las cuales fueron superiores (P<0,05) hasta los 21 d de evaluación en CP y SP. El tipo de empaque y el tiempo de enfriamiento influyeron en la concentración de NC. El VP tuvo el nivel más bajo de PU y bacterias mesófilas hasta los 21 d de almacenamiento.

Palabras clave: Contaminación bacteriana; carne; empaque; conejo

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INTRODUCTION

Meat is one of the most perishable foods due to its high-water content and available nutrients. Still, when there are physical changes in color, smell, texture, oxidation, and growth of microorganisms, there is a rejection of meat from the consumers. A bacterial load greater than 10^7 colony forming units· square centimeter^{-1} (CFU·cm^{-2}) in the meat packets causes a bad smell, and an amount of 10^9 CFU·cm^{-2} the smell was putrid, causing decarboxylation of the free amino acids [8]. During the decomposition of the meat, there is a formation and accumulation of nitrogenous compounds (NC) [22, 31]. The quantification of the NC in the meat indicates the beginning of the microbial activity and its deterioration in nutritional value [21, 22].

There are two standard packaging systems; these are the conventional polystyrene foam tray and vacuum packaging [7]. Specifically, there is no information on rabbit (*Oryctolagus cuniculus*) meat quality over shelf life. The objective of the study was to identify NC production, microbial contamination, and some quality parameters in rabbit meat, using three types of packaging at different storage times.

MATERIAL AND METHODS

Study place

The animals were obtained from the rabbit farm of the Chapingo University, Mexico, located at 19°29' North and 98°54' West [17]. Physicochemical analyses of the meat and the identification of bacteria were carried out in the Facultad de Estudios Superiores, Cuautitlán of the National University.

Selection and slaughter of rabbits

Sixty adult male rabbits, New Zealand breed, were divided into three experimental treatments (T), homogeneous in weight (2.35 ± 0.25 kilograms (kg). Each T was housed in three-place cages (30×42 centimeters -cm-, height 30 cm). All the animals were slaughtered not longer than 2 minutes (min) after each animal was removed from its cage. The procedure was bled by cutting the jugular vein and the carotid artery (less than 30 seconds –s –) and then the skin, genitals, urinary bladder, gastrointestinal tract and distal parts of legs were removed [14].

Obtaining samples

Previously, a refrigerator (Imbera, VR19, Koblens, USA) was assigned to preserve the meat samples, and it was disinfected with 10% of the nitric acid solution and washed with distilled and deionized water. Then, 30 grams (g) of the *Longissimus thoracis et lumborum* muscle of each animal was obtained. Each sample was divided into six portions of 5 g and two groups were formed (3 sub-samples in each group). The first group was used to measure the physicochemical characteristics of the meat, and the second group was used to quantify NC and bacterial isolation.

All samples were identified inside plastic bags and refrigerated (4°C) at times zero (less than 12 cooling hours -h-: 0, 7, 14, and 21 days -d-, 45 samples for each T-time). Subsequently, the samples stored for each time were randomly divided into 15 samples for each type of packaging, classified into the following Ts:

1. Control-plastic (CP), samples covered with a transparent plastic bag (polyethylene). 15×25 cm. Caliber: 18 milimicra (µm).
2. Polyethylene tray with semi-permeable plastic film (SP): Unicel tray (Reyma®) with 11 cm diameter and a flexible food-grade film (12 µm).
3. Vacuum packing (VP): Vacuum bags of 15×20 cm and 90 µ·2.8 mililiters^{-1} -mL- (Torrey® packer model-Evd20); the vacuum time was 40 s and the sealing of 2 s.

Physical measurements of meat

The pH and colorimeter electrodes were previously disinfected between each sample with a 10% nitric acid solution and washed with deionized water.

Meat pH

A portable potentiometer (HANNA model-HI99163, USA) was used. The electrode was pressed moderately on the surface of each sample, and the pH reading was recorded for four consecutive times.

Meat color

A Hunter Lab portable colorimeter (CR-410, Konica-Minolta, Inc. Japan) was used to measure the variables L* (luminosity), a* (red-green) and b* (yellow-blue). It was calibrated with the tile to the reference coordinates: L* = 94.7, a* = 0.3130, b* = 0.3191); subsequently, three points were measured on the surface area of the meat sample.

Bacteriological tests

Samples of 5 g of meat were mixed with 45 mL of sterile physiological saline; serial dilutions were prepared up to 1:1000. Two agar media Standard (Bioxon®) was used for the quantify *Enterobacteriaceae* (Violet Red Bile Glucose Agar: MH581) and total aerobic mesophilic (Plate Count Agar: ICMSF – 2000). The incubation was carried out from 24 to 48 h at 35°C, in a Felisa® equipment (Felisa: FE-500, Feligneo, México). The volume spread calculated the number of colonies that arose on a pour plate at the end of the designed time.

Quantification of nitrogenous compounds

The samples were removed from the assigned packing and they were macerated to measure NC through a 3-phase procedure [22]:

First phase. Preparation of solution and individual standards of the NC: In each tube, putrescine (PU), cadaverine (CA), histamine (HI) standards (Sulpenco, Merck, USA) were weighed to have a concentration of 10 milligrams·mL^{-1} (mg·mL^{-1}). Each standard was diluted in 1 mL of hydrochloric acid and homogenized (base solution).

Second phase. Extraction: 5 g of each meat sample was weighed into test tubes, and 5 mL of perchloric acid (6%) was added, homogenizing in the vortex (Scientific Industries, SI-0236, USA) and allowed to stand for 1 h in refrigeration. All samples were centrifuged (Universal 320/320R Hettich® ,México) at 4950G-force (10 min at 4°C), and the solutions were filtered, adding 1 mL of 2 Molar (M) NaOH. The pH was maintained at 6 and the tubes were kept in ice water for 20 min. **Derivatization:** All tubes were removed from the cold water, and 20 microlliters (µL) of benzoyl chloride was added and homogenized. They were left at rest for a further 20 min and 2 mL of 5 M sodium chloride was added, homogenizing in a vortex, and one mL of ethyl ether was added. Then, the ether sample was evaporated with a flow of nitrogen (10 min) and 500 µL of Milli Q water and 500 µL of acetonitrile were added and vortexed.

High-performance liquid chromatography

Third phase: The filtered sample (1 mL) was injected into the High-performance liquid chromatography (HPLC) with a diode detector array (Model 1100 Horse Power(HP) Agilent Technologies. Wilmington, USA). An elution gradient program was used with a 50:50 mixture, acetonitrile as solvent A and purified ultrapure water as solvent B. The flow rate used was 1 mL·min^{-1}. The temperature of the column was 40°C, and the effluent from the column was analyzed at 254 nanometers.

Statistical analysis

All rabbits were randomly distributed with a 4×3 factorial arrangement. The normal distribution in the number of bacterial colonies was determined with the Kolmogorov-Smirnov test. All the variables were analyzed with a PROC MIXED design [28] and the mean comparison was made with the PDIFF test, using the statistical package [28].

RESULTS AND DISCUSSION

pH and bacterial count

TABLE I shows all results. The pH in the CP, SP, and VP Ts decreased 0.74, 0.85, and 1.08 units (u) from 0 to 21 d, respectively. There were no differences (P>0.05) in pH between the three Ts at storage times of 0, 7, and 14 d, the value of pH=6.7 was within the range reported by other authors [4, 23]. Except for 21 d, the pH of the CP T was higher (6.28, P<0.05) and decreased 0.21 and 0.45 u for the SP and VP Ts (P<0.05), respectively [9]. Possibly, this effect is due to the accumulation of lactic acid, which could cause protein denaturation and water retention decreased [15]. The lower concentration of pH in the VP T was possibly due to the higher content of lactic acid accumulated in this type of packaging and a lower bacterial proliferation of *aerobic mesophiles* and *Enterobacteriaceae* (TABLE I), due to the vacuum process (EVAC-8-RHI, Inox, NH_Rhino, China). Other authors report that contamination with bacteria and some fungi could induce the formation of alkaline compounds [2,16], causing the decomposition of meat and increase of pH and ammonia [4, 30].

Color

The L* value decreased (P<0.05) 2.52, 3.99, 4.96 u from 0 to 21 d for the CP, SP and VP Ts (TABLE I). Contrarily the values of a* and b* increased (P<0.05) 2.85, 3.07, 3.27, and 5.96, 7.77, 4.06 u from 0 to 21 d for the CP, SP and VP Ts, respectively. The L* and a* indices between the CP, SP and VP Ts did not show significant differences (P>0.05) from the times 0 to 21 d; except fora decrease of 2.4 u in L* of SP T compared with VP T. The b* index was similar in all Ts at 0 d (P>0.05), although from 7 to 21 d of the SP T (average: 11.7) was increased 1.63 u, while the VP T (average 7.25) decreased 2.82 u (P<0.05), both compared to the CP T (average 10.07).

The L* decreased with the cooling time, but the index a* and b* increased (P<0.05) in the three types of packages evaluated. There is no published data on rabbit meat, but color values were similar to bovine meat [10, 25]. L* value was influenced by the concentration of reduced myoglobin, oxymyoglobin, and metmyoglobin [13] and the index a* and b* increase with the maturity time of meat due to the greater passage of light in the meat tissue. Maybe it was associated with the opening of the packages, and the meat had contact with oxygen due to which myoglobin was transformed into oxymyoglobin and, it was intensifying the brightness and red color [24].

TABLE I

Physico-chemical variables and bacterial count (mean ± sd) in three of packaging at different days of refrigeration in rabbit meat (muscle *Longissimus thoracis et lumborum*)

	Refrigeration days			
	0	**7**	**14**	**21**
Control Plastic (CP)				
pH	6.65 ± 0.05cA	5.70 ± 0.01aA	5.74 ± 0.05aA	6.28 ± 0.14bC
Meat colour				
L*	58.97 ± 1.03cA	57.60 ± 0.48bcA	56.44 ± 0.47abA	55.30 ± 0.53aAB
a*	14.62 ± 0.86aA	17.34 ± 0.39bA	17.16 ± 0.46bA	17.93 ± 0.85bA
b*	4.11 ± 0.80aA	9.57 ± 0.23bB	10.54 ± 0.27bB	10.11 ± 0.31bB
Semi-permeable (SP) plastic film)				
pH	6.69 ± 0.05cA	5.74 ± 0.04aA	5.71 ± 0.03aA	6.07 ± 0.11bB
Meat color				
L*	60.05 ±1.26cA	57.55 ± 0.53bA	56.98 ±0.66bA	53.64 ± 0.73aA
a*	15.06 ± 1.14aA	17.97 ± 0.43bA	17.96 ± 0.42bA	18.47 ± 0.47bA
b*	3.98 ± 0.88aA	11.45 ± 0.35bC	11.53 ± 0.27bB	12.29 ± 0.39bC
Vacuum packing (VP)				
pH	6.70 ± 0.05bA	5.55 ± 0.03aA	5.58 ± 0.03aA	5.73 ± 0.03aA
Meat color				
L*	60.39 ± 0.78cA	58.20 ± 0.51bA	56.50 ± 0.78abA	56.08 ± 0.45aBC
a*	13.71 ± 0.67aA	17.00 ± 0.36bA	16.95 ± 0.37bA	17.01 ± 0.29bA
b*	3.19 ± 0.41aA	7.06 ± 0.21bA	7.45 ± 0.21bA	7.26 ± 0.16bA

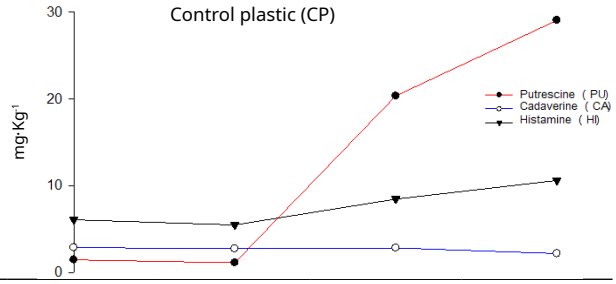
CP: Polyethylene plastic bag, SP: Polyethylene tray with semipermeable plastic film, VP: Vacuum packed (vacuum time 40 seg and sealing 2 seg), s.d.: standard deviation, L*: luminosity, a*: index color red-green, b*: index color yellow-blue. a-c: Different lowercase letters in the same rows indicate significant differences between storage days (P<0.05). A-C: Different capital letters in the same column indicate significant differences between packages (P<0.05)

Nitrogenous compounds and bacterial contamination

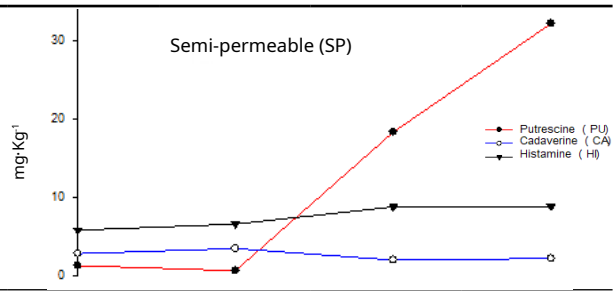
The PU content did not show significant differences (P> 0.05) between the three T during the first 7 d storage (TABLE II). Then, PU increased drastically (P<0.05) from 7 to 21 d of storage. CA and HI had significant differences (P<0.05) from 14 to 21 d between the SP and VP T. The storage time and the type of packaging mainly influenced the production of PU, and a high level of PU is associated with the proliferation of *Pseudomonas* spp. in aerobic conditions at 37°C [1]. The PU was the main NC formed; its value was similar to another report in chicken*(Gallus gallus familiaris)* (45.2 mg·kg^{-1} [22]) during 17 d of storage. In contrast, the average concentration of CA in the three T was lower (2.54 mg·kg^{-1}) than reported (5.7 mg·kg^{-1}) in chickens at the end of the evaluation. CA and HI at 7 d of storage had a higher concentration than in bovine (*Bos taurus*) meat (1.85 and 2.11 mg·kg^{-1}), stored for 7 d in trays packing with trays of polystyrene [12].

The production of CA in rabbit meat is possibly associated with lysine; this amino acid was the precursor of NC [5]. *Enterobacteriaceae* also induced the highest CA content [6]. However, the number of these bacteria was lower than that reported by other authors [1, 12], which suggests that a smaller amount of *Enterobacteriaceae* is associated

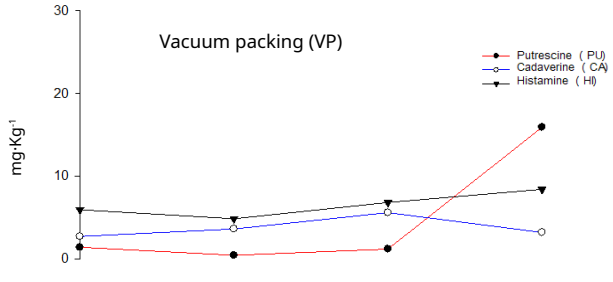
TABLE II
Concentration of nitrogenous compounds (mg·kg^{-1} = mean ± s.d.) in three types of packaging on different days of refrigeration in rabbit meat (*Longissimus thoracis et lumborum*)



Day	0	7	14	21
PU	1.47 ± 0.23aA	1.13 ± 0.18aA	20.36 ± 9.3bB	29.08 ± 7.4bB
CA	2.89 ± 0.45aA	2.75 ± 0.39aA	2.84 ± 0.47aA	2.20 ± 0.60aA
HI	6.09 ± 0.85aA	5.49 ± 0.26aA	8.47 ± 0.99bA	10.62 ± 1.59bA
En	Un	3.69 ± 0.89aA	3.83 ± 1.23aAB	6.02 ± 0.83aB
Mes	2.24 ± 0.57aA	4.07 ± 0.24abA	5.66 ± 0.49bB	4.95 ± 0.77bA



PU	1.31 ± 0.20aA	0.67 ± 0.04aA	18.30 ± 7.34bB	32.12 ± 9.8cB
CA	2.84 ± 0.52aA	3.49 ± 0.44aA	2.03 ± 0.21aA	2.23 ± 0.20aA
HI	5.83 ± 0.64aA	6.60 ± 0.46aA	8.79 ± 0.91bA	8.87 ± 1.41bA
En	3.33 ± 0.70a	Un	6.05 ± 0.64aB	3.99 ± 1.3aAB
Mes	3.54 ± 0.58bcA	2.53 ± 0.62abA	4.29 ±1.2bcAB	4.87 ± 0.7cA



PU	1.40 ± 0.20aA	0.44 ± 0.03aA	1.19 ± 0.16aA	15.93 ± 2.1bB
CA	2.71 ± 0.83aA	3.62 ± 0.64aA	5.59 ± 1.13bB	3.20 ± 1.3aA
HI	5.94 ± 0.5abA	4.86 ± 0.46aA	6.83 ± 0.6bcB	8.42 ± 0.1bcA
En	Un	3.30 ± 0.10aA	1.98 ± 0.08aA	2.32 ± 0.34aA
Mes	3.19 ± 0.5aA	3.36 ± 0.3aA	2.99 ± 0.8aA	4.34 ± 1.1aA

CP: Polyethylene plastic bag, SP: Polyethylene tray with semipermeable plastic film, VP: Vacuum packed (vacuum time 40 seg and sealing 2 seg). s.d.: standard deviation, En: *Enterobacteriaceae,* Mes: *Mesophiles,* Un: Undetermined, a-c: Different lowercase letters in the same rows indicate significant differences between storage days (P<0.05), A-C: Different capital letters in the same column indicate significant differences between packages (P<0.05)

with a lower amount of CA. On the other hand, the PU content compared to CA was similar to other studies [19, 29]. Also, NC can be formed by the degradation of glutamine, arginine, and agmatine. Arginine is easily converted into agmatine by the decarboxylation of arginine by agmatine-deiminase and transformed to PU [6,18].

Although, HI concentration was greater than the CA [12, 19] and CA concentration was not a risk of intoxication in this study, the permissible CA limit was about 40 mg [18, 27]. The increase of NC was given with the cooling time [1, 20]. In this regard, Vinci and Antonelli [32] evaluated the amount of NC in bovine meat and chicken meat; finding that NC production differs between two types of meat up to 15 d of storage. The proteolytic enzymes easily attack meat chicken, and consequently, there is better availability of amino acid precursors for NC. In the case, rabbit meat has small fibers, but the collagen content of the *Longissimus muscle* is higher (7.0 mg·g^{-1}) when compared to the collagen of pigs (*Sus scrofa domesticus*) (5.9 mg·g^{-1}), bovines (3.4-5.8 mg·g^{-1}) and chickens (3-4 mg·g^{-1}). The collagen causes greater hardness of the meat and possibly prevents the attack of the proteolytic enzymes, consequently there may be less availability of amino acid precursors for the formation of NC [26]. So, the lower content of NC in rabbit meat can be due to this effect explained and, the activity amino acid-decarboxylase influenced by bacteria [1, 12]. Temperature, oxygen availability, redox potential, and pH [11, 30] are other factors that also participate in the NC formation.

The detection of HI in chicken meat was reported from 11 d of storage [1] and in fish (*Cyprinus carpio*) meat on the 3$^{th.}$ d, with a maximum peak at 12 d of storage [4]. In this study, the three types of packaging showed an increase in HI with storage time. In reference, PU in the CP and SP packages was related to the presence of high oxygen and less carbon dioxide levels, unlike the VP generating selective microbial proliferation [29]. The most common bacteria in VP were aerobic mesophiles and *Enterobacteriaceae* [1]. The aerobic mesophiles were higher at the end of the evaluation in the CP and SP (~4.7), but the VP T was similar throughout this experiment (TABLE II). It is difficult to have a direct correlation between the counts of microorganisms and NC [6]; although in this study was observed that the PU content and the aerobic mesophiles count were higher in the CP and SP. The results were similar with beef vacuum packed, where the count of aerobic mesophiles [8] and *Enterobacteriaceae* [3, 8, 9] increased in 14 d of storage. Currently, there is interest in *Enterobacteriaceae* detection in food samples, because these microorganisms are a public health risk by toxicological effects.

CONCLUSION

The storage time changed the variables of color, pH, NC content, and bacterial count. At the end of the evaluation (21 d), there were differences in conservation time and the packaging type. The number of *Enterobacteriaceae* was not altered by the storage time. The type of packaging and the cooling time influenced the concentration of NC; mainly the VP had the lowest concentration of PU and mesophilic bacteria until 21 d of storage.

Conflict of interest

The authors declare no potential conflicts of interest.

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Ethics Approval

The study was approved and conducted in accordance with the guidelines of the Institutional Animal Care of Colegio de Postgraduados. México. (Approval ID: 09-2019).

BIBLIOGRAPHIC REFERENCES

[1] BALAMATSIA, C.C.; PALEOLOGOS, E.K.; KONTOMINAS, M.G.; SAVVAIDIS, I.N. Correlation between microbial flora, sensory changes and biogenic amines formation in fresh chicken meat stored aerobically or under modified atmosphere packaging at 4°C: possible role of biogenic amines as spoilage indicators. **Antonie Van Leeuwenhoek** 89: 9–17. 2008. https://doi.org/db7bn5.

[2] BARREIRO, J.; SANDOVAL, A. Carne. In: **Operaciones de Conservación de Alimentos por Bajas Temperaturas**. 1ra. Ed. EQUINOCCIO, Universidad Simón Bolívar, Venezuela. Pp. 115-118. 2006.

[3] BELLÉS, M.; ALONSO, V.; RONCALÉS, P.; BELTRÁN, J.A. The combined effects of superchilling and packaging on the shelf life of lamb. **Meat Sci.** 133: 126–132. 2017. https://doi.org/jmq4.

[4] BITA, S.; MALEKPOURI, P.; MOHAMMADIAN, T.; NAJAFZADEH, H.; KOCHANIAN, P. Changes in biogenic amines and microbial loads in the muscle of orange-spotted grouper, Epinephelus coioides (Hamilton, 1822) during ice storage. **J. Food Sci Technol. -Mysore-** 52: 240–248. 2015. https://doi.org/jmq5.

[5] BLAS, C.; DE WISEMAN, J. Influence of diet on rabbit meat quality. **Nutrition of the Rabbit.** 2nd. Ed. CABI, Wallingford, Cambridge, MA. Pp. 163-178. 2010.

[6] BOVER, S; LATORRE, M.; GARRIGA, M.; VIDAL, C.M. Aminas biógenas en productos cárnicos: un repaso a su origen, importancia y control. **Eurocarne.** 141: 1-6. 2005.

[7] CHARLES, N.; WILLIAMS, S.K.; RODRICK, G.E. Effects of packaging systems on the natural microflora and acceptability of chicken breast meat. **Poult. Sci.** 85: 1798–1801. 2006. https://doi.org/jmq6.

[8] ERCOLINI, D.; RUSSO, F.; TORRIERI, E.; MASI, P.; VILLANI, F. Changes in the Spoilage-Related Microbiota of Beef during Refrigerated Storage under Different Packaging Conditions. **Appl. Environm. Microbiol.** 72: 4663–4671. 2006. https://doi.org/c47ch6.

[9] FLORES-RONDÓN, C.; LEAL, M.; RUIZ-RAMÍREZ, J.; SÁNCHEZ, E.; MORENO, M.; CASTRO, G.; BARBOZA, Y. Tiempo de almacenamiento e identificación de bacterias ácido lácticas en carnes de res picada empacadas al vacío. **Rev. Científ. FCV-LUZ.** XXI(5): 425–433. 2011.

[10] FRANCO, J.; FEED, O.; BIANCHI, G.; GARIBOTTO, G.; BALLESTEROS, F.; NAN, F.; PERCOVICH, M.; PIRIZ, M.; BENTANCUR, O. Parámetros de calidad de carne en cinco músculos de novillos Holando durante la maduración post- mortem III. Calidad Sensorial. **Agrocien. Urug.** 12: 74–79. 2008.

[11] FU, Q.Q.; GE, Q.F.; LIU, R.; WANG, H.O.; ZHOU, G.H.; ZHANG, W.G. Influence of modified atmosphere packaging on protein oxidation, calpain activation and desmin degradation of beef muscles. **J. Sci. Food Agric.** 97: 4508–4514. 2017. https://doi.org/jmq8.

[12] GALGANO, F.; FAVATI, F.; BONADIO, M.; LORUSSO, V.; ROMANO, P. Role of biogenic amines as index of freshness in beef meat packed with different biopolymeric materials. **Food Res. Int.** 42: 1147–1152. 2009. https://doi.org/cx5kcp.

[13] GIL, H.A. Tratado de Nutrición. **Composición y calidad nutritiva de los alimentos.** 2da. Ed. Editorial Médica Panamericana, Buenos Aires. Argentina. 576 pp. 2010.

[14] GOBIERNO DE MEXICO. NOM-008-ZOO-1994. Especificaciones zoosanitarias para la construcción y equipamiento de establecimientos para el sacrificio de animales y los dedicados a la industrialización de productos cárnicos. Norma Oficial Mexicana. 1994. Online: https://bit.ly/3UZ7XoU. 13/01/2022.

[15] HUFF-LONERGAN, E.; LONERGAN, S.M. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science. **51st. International Congress Meat Science Technology. (ICoMST).** 71: 194–204. 2005. https://doi.org/dkqpn8.

[16] HUI, Y.H.; GUERRERO, I.; ROSMINI, M.R. Aplicaciones prácticas para la conservación e industrialización de carnes rojas y productos cárnicos. In: **Ciencia y Tecnología de Carnes.** Editorial Limusa, México, DF. Pp.117–143. 2006.

[17] INSTITUTO NACIONAL PARA EL FEDERALISMO Y EL DESARROLLO MUNICIPAL. Estado de Oaxaca. **Encyclopedia de los Municipios y Delegaciones de México.** Estado de México. Texcoco. Pp 35-46. 2015. https://bit.ly/3TEwY85. 13/01/2021.

[18] JAIRATH, G.; SINGH, P.; DABUR, R.; RANI, M.; CHAUDHARI, M. Biogenic amines in meat and meat products and its public health significance: a review. **J. Food Sci. Technol.** 52: 4–15. 2015. https://doi.org/f7wb4t.

[19] KANIOU, I.; SAMOURIS, G.; MOURATIDOU, T.; ELEFTHERIADOU, A.; ZANTOPOULOS, N. Determination of biogenic amines in fresh unpacked and vacuum-packed beef during storage at 4°C. **Food Chem.** 74: 515–519. 2001. https://doi.org/bd9qf7.

[20] LÁZARO, C.; CONTE Jr, C.; CUNHA, F.; MARSICO, E.; BORGES, S.; FRANCO, R. Validation of an HPLC Methodology for the Identification and Quantification of Biogenic Amines in Chicken Meat. **Food Anal. Meth.** 6: 1024–1032. 2013. https://doi.org/jmrh.

[21] LAZARO, C.; CONTE-JUNIOR, C.A.; MEDINA-VARA, M.; MOTA-ROJAS, D.; CRUZ-MONTERROSA, R.; GUERRERO-LEGARRETA, I. Effect of pre-slaughter confinement stress on physicochemical parameters of chicken meat. **Ciên. Anim. Bras.** 20: 1–11. 2019. https://doi.org/jmrj.

[22] LAZARO, C.A.; CONTE-JÚNIOR, C.A.; CANTO, A.C.; MONTEIRO, M.L.G.; COSTA-LIMA, B.; CRUZ, A.G.; MÁRSICO; E.T.; FRANCO, R.M. Biogenic amines as bacterial quality indicators in different poultry meat species. **LWT-Food Sci. Technol.** 60: 15–21. 2015. https://doi.org/jmrk.

[23] LAZZARONI, C.; BIAGINI, D.; LUSSIANA, C. Different rearing systems for fattening rabbits: Performance and carcass characteristics. **Meat Sci.** 82: 200–204. 2009. https://doi.org/b7zw5q.

[24] MANCINI, R.A.; HUNT, M.C. Current research in meat color. Meat Science. **51st. International Congress Meat Science Technology. (ICoMST).** 71: 100–121. 2005. https://doi.org/dks36s.

[25] MORENO, T.; CARBALLO, J.A.; MONSERRAT, L. Estudio de la calidad de la carne de ternera de raza rubia gallega a lo largo de la maduración al vacío. **Arch. Zoot.** 55: 13. 2006.

[26] PASCUAL, M.; PLA, M. Changes in collagen, texture and sensory properties of meat when selecting rabbits for growth rate. **Meat Sci.** 78: 375–380. 2008. https://doi.org/c3p5hx.

[27] RABIE, M.A.; PERES, C.; MALCATA, F.X. Evolution of amino acids and biogenic amines throughout storage in sausages made of horse, beef and turkey meats. **Meat Sci.** 96: 82–87. 2014. https://doi.org/jmrm.

[28] STATISTICAL ANALYSIS SYSTEM INSTITUTE. Statistical Analysis Software, Version 9.4. SAS/STAT. Online: https://bit.ly/3UMdeAv.13/01/2022.

[29] SIGNORINI, M. Microbiología de carnes envasadas al vacio y la biopreservación como medio para prolongar la vida de anaquel. **Nacameh.** 1: 26–40. 2007.

[30] SIGNORINI, M.L.; GUERRERO-LEGARRETA, I. Producción de aminas biogénicas en carne de bovino conservada con ácido láctico de origen químico y bacteriano. **Rev. Mex. Ing.Quím.** 8: 41–49. 2009.

[31] TAMIM, N.M.; DOERR, J.A. Effect of Putrefaction of Poultry Carcasses Prior to Rendering on Biogenic Amine Production. **J. Appl. Poult. Res.** 12: 456–460. 2003. https://doi.org/jmrq.

[32] VINCI, G.; ANTONELLI, M. Biogenic amines: Quality index of freshness in red and white meat. **Food Control.** 13: 519–524. 2002. https://doi.org/cmrf7s.