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Influence of thermal processing on color, chemical composition, lipid oxidation and microbiological characteristics of guinea pig (*Cavia porcellus*) meat

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SUMMARY: The objective of the present study was to evaluate the impact of two heat treatments on the chromatic parameters, chemical composition, lipid oxidation and microbiological characteristics of guinea pig (*Cavia porcellus*) meat. The contents of protein, fat, ash, and thiobarbituric acid reactive substances did not differ significantly for treatments of pasteurization and sterilization. The main fatty acids were linoleic (~35%), palmitic (~23%) and oleic (~19%). The atherogenic index ranged from 0.56 to 0.58, the thrombogenic index ranged from 0.64 to 0.66, and the hypo/hypercholesterolemic (h/H) ratio ranged from 2.55 to 2.57. Pasteurization and sterilization treatment did not substantially affect the acid profile or healthy lipid indices. Regarding microbial load, both heat treatments were effective against coliforms, molds and yeast, and *Salmonella* spp. Heat treatments effectively reduced bacterial load without significantly altering the physicochemical quality of guinea pig meat.

KEY-WORDS: *Carcass quality; Fatty acids; Guinea pig; Peru; Protein; Thermal treatment.*

RESUMEN: ***Influencia del procesamiento térmico sobre el color, composición química, oxidación lipídica y microbiología de la carne de cuy*** **(Cavia porcellus).** El objetivo del presente estudio fue para evaluar el impacto de dos tratamientos térmico sobre los parámetros cromáticos, la composición química, oxidación lipídica y características microbiológicas de la carne de cuy (*Cavia porcellus*). El contenido de proteínas, grasa, cenizas, y las sustancias reactantes de ácido tiobarbitúrico no difirió significativamente para el tratamiento de pasteurización y esterilización. Los principales ácidos grasos fueron el linoleico (~35%), palmítico (~23%) y oleico (~19%). El índice aterogénico oscilo entre 0,56 a 0,58, el índice trombogénico vario de 0,64 a 0,66 y la relación hipo/hipercolesterolémico (h/H) vario de 2,55 a 2,57. El tratamiento de pasterización y esterilización no afecto sustancialmente el perfil de ácidos ni los índices lipídicos de salud. Respecto a la carga microbiana ambos tratamientos térmicos fueron efectivos para coliformes, mohos y levadura y *Salmonella* spp. Los tratamientos térmicos redujeron eficazmente la carga bacteriana sin alterar significativamente la calidad fisicoquímica de la carne de cuy.

PALABRAS CLAVE: *Ácidos grasos; Calidad de la carcasa; Cuy; Perú; Proteínas; Tratamiento térmico.*

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1. INTRODUCTION

Guinea pig ("Cuy", is the common name in Peru) (*Cavia porcellus*), is a native species of the Andean diet of Peru, Ecuador, Bolivia and Colombia, and is a native food product with high nutritional quality. In Peru, guinea pig and the popular gastronomic traditions are closely related, and a couple of typical dishes are made from guinea pig meat, namely, "picante de cuy" and "cuy chactado" (in Spanish).

Meat is a source of high-quality animal protein. The protein and lipid composition ranges between 20.02 and 7.80%, respectively, with the nutritional composition of other red meats, such as beef at (16.5% protein and 17.0% fat), pork (11.2% protein and 23.0% fat), lamb (20.8% protein and 17.0% fat) (Kauffman, 2012), and the composition in poultry meat, such as turkey (13.7% protein and 11.9% fat) and duck (12.8% protein and 13.8% fat) (Soriano-Santos, 2010).

According to NTP 201.057 (2016) the meat is the muscular part of the canal or carcass formed by the soft tissue that surrounds the bone structure, including its fat, tendons, vessels, nerves and aponeurosis. In the case of guinea pig, the carcasses are presented as whole carcasses (with or without giblets), half guinea pig carcass (longitudinal cut into two symmetrical parts), quarter of guinea pig carcass (from longitudinal and transverse cut of the carcass into two forequarters and two hindquarters); forequarter, including the soft-tissue neck from the atlanto-occipital joint to the first lumbar vertebra and the hindquarter, from the kidney's anterior border from the second lumbar vertebra to the last coccygeal vertebrae (NTP 201.058, 2016). In the Peruvian market, guinea pig meat is sold in different presentations. Vacuum packed meat in the form of whole guinea pig (without head and without legs), and boneless guinea pig in conventional or vacuum-sealed packaging in fresh state are the most commercialized. These products offer sanitary conditions and required quality.

Post-mortem meat quality depends on perimortal factors related to the physiological and biochemical aspects of the meat as well as the temperature for the determination of quality attributes. These attributes include color, water-holding capacity, and texture. The acceptability and satisfaction of meat products for consumers is influenced by nutritional value, healthiness and organoleptic characteristics which include juiciness, flavor, and tenderness.

The heat treatment of foods rich in protein and fat (polyunsaturated fatty acids, PUFAs) can lead to relevant changes in nutritional composition and significantly increase most of the oxidation markers (Bejaoui *et al*., 2019). The long-chain (LC) PUFAs, namely, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are especially susceptible to oxidation during food processing and other culinary treatments. The heat treatment generates several positive effects on meats, such as inhibition of microorganism, increased shelf-life, improved digestibility and improve quality parameters, among them the color, which is considered a reliable indicator of safety and doneness (Gladyshev and Sushchik, 2019). Despite its growing commercial relevance, studies evaluating how thermal processing affects the nutritional and microbiological quality of guinea pig meat are limited.

Therefore, this study aimed to evaluate the effects of pasteurization and sterilization on the color, chemical composition, lipid oxidation, and microbiological quality of guinea pig meat.

2. MATERIALS AND METHODS

2.1. Animals and sample preparation

A total of ten guinea pigs (type 1, improved males) from the Cieneguilla farm of the National Agrarian University of La Molina were used. The guinea pigs had an average age of 115 days and an average weight of 740 g. They were fed 150 to 200 g of forage (fresh corn leaves) and 50 g of balanced feed, which consisted of soybean meal, corn flour, wheat germ, gluten, methionine, calcium carbonate, salt and vitamin C. The slaughter was carried out following the instructions of the technological booklet No. 21 proposed by the FAO (2000). The guinea pig was peeled in hot water at 85 °C for 15 s. The carcasses were then placed in plastic boxes with ice and inspected for quality based on the following parameters: appearance, odor, color, texture, and pH. The carcasses were then eviscerated, the head and feet removed and then disinfected with chlorinated water (0.1 ml/L). The carcasses were cut into 2 sections and formed into 4 quarters (hindquarter

and forequarter) to obtain a homogeneous and representative sample. The sample was divided into three treatments: raw, pasteurized (92 °C for 30 min), and scalded (121 °C for 20 min). The weight for each treatment was 600 g, which included meat, skin, and bones. The limitation related to the number of animals was due to ethical considerations, since a larger number of animals produces unnecessary waste and resources.

2.2. pH measurement

100 mL of distilled water were added to approximately 10 g of sample and then homogenized in a blender (Oster 4655) for 2 min. Finally, the pH was read using a potentiometer (Orion 3-Star Benchtop pH Meter, Thermo Scientific) calibrated with buffer solutions of 4, 7 and 10.

2.3. Color measurements

Images were captured using an iPhone X smartphone with a 12-megapixel wide-angle and telephoto camera (resolution of 2436 x 1125 pixels (458 pixels per inch) (Apple Inc., USA) in a mini photo studio under 36 W daylight and 6200 K color temperature (Philips, USA) at 20 cm and an angle of 45°. The images were subsequently analyzed using the Color Inspiration Tool app available on the App Store. A total of 10 samples from the hind leg, foreleg, and skin were photographed. The results for the L^*, a^*, and b^* color coordinates were obtained directly from the app., while chroma (C^*) and hue angle ($H°$) were obtained from equations 1 and 2.

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (1)$$

$$H° = tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (2)$$

Where: a^* represents the red-green axis, and b^* represents the yellow-blue axis.

2.4. Proximate composition

The determinations of protein content (LABS-ITP-FQ-001) and fat content (LABS-ITP-FQ-003) were carried out following the procedure described by the laboratory of the Technological Institute of Production. The determination of moisture content was carried out following the procedure described by the official method of AOAC 934.01 and the ash content was determined in a muffle furnace at 600 °C with 2 g of sample, according to the methodology described in AOAC 942.05 (AOAC, 2000). The nitrogen-free extract (NFE) content was calculated by difference, using equation 3, while the gross energy value was determined using equation 4 (Frunză et al., 2023).

$$\text{NFE}\ (g/100g) = 100 - water - ash - proteins\ -\ lipids \quad (3)$$

$$\text{Gross energy}\ (kcal/100g) = g\ proteins \times 4.27 + g\ fat\ \times 9.02 + g\ NFE\ \times 3.87 \quad (4)$$

2.5. Thiobarbituric acid reactive substances (TBARS) determination

The thiobarbituric acid reactive substances (TBARS) method was applied according to the methodology proposed by Erkan and Özden (2008). Approximately 5 g of the crushed sample were placed in a 250 mL ground joint Erlenmeyer flask, then 25 mL of 7.5% trichloroacetic acid were added and the mixture was stirred in a multi-position digital stirring device (Thermo Scientific) for 30 min. The solution was then filtered through Whatman No. 40 filter paper, and 5 mL were taken and mixed with 5 mL of 2% TBA. The mixture was boiled for 40 min, then cooled to 20 °C and centrifuged at 2000 rpm (Eppendor centrifuge-5702) for 10 min. After the mixture was tempered, absorbance readings were taken at 532 nm on a Genesys 10S UV-Visible Spectrophotometer (Thermo Scientific). The results were calculated by multiplying the absorbance value by 10.2. TBARS values were expressed in terms of milligrams of malonaldehyde equivalents per kilogram of sample (mg MDA/kg).

2.6. Analysis of fatty acid composition

A 100 g sample was homogenized in a blender (Oster 4655) with a mixture of 100 mL of chloroform and 200 mL of methanol for 2 min. An additional 100 mL of chloroform and 100 mL of distilled water were then added to the mixture, and the mixture was stirred manually for 30 s. The homogenate was filtered through Whatman No. 1 filter paper in a Büchner funnel with gentle suction. The filtrate was transferred to a separatory funnel for 3 h and the chloroform phase was recovered. The solution was then filtered through Whatman No. 41 filter paper containing 5 g of sodium sulfate. The organic phase was evaporated using a rotary evaporator, and the extracted fat was stored in glass tubes under refrigeration at 5 °C.

A 50 mg aliquot of fat was placed in a test tube, then 2.5 mL of petroleum ether were added and vortexed. Next, 0.25 mL of 2 N NaOH in methanol were added and vortexed vigorously for a few seconds. The mixture was then placed in a water bath at 50 °C for 20 s and vortexed. Finally, 0.30 mL of 2N HCl in methanol were added and vortexed. Once the two phases were separated, the organic fraction containing the fatty acid methyl esters (FAMEs) was placed in a glass vial for chromatographic analysis.

The FAME profile was obtained by gas chromatography coupled with a flame ionization detector (Perkin Elmer Autosystem XL). FAME separation was performed on a SUPELCOWAX 10 fused silica capillary column, 30 m x 0.25 mm I.D., 0.25 μm film thickness was provided by Supelco, Bellefonte, PA, USA. The injector temperature was 250 °C, the injection volume was 2 μL. the injection mode was split 100:1. and the detector temperature was 270 °C. The carrier gas through the stationary phase was hydrogen with a constant linear velocity of 35 cm/s. The analysis conditions in the oven were: initial oven temperature: 160 °C (hold for 2 min); 4 °C/min to 220 °C; 2 °C/min to 230 °C (hold for 8 min). The total run-time was 65 min. The identification of the FAMEs was carried out by comparing their sample retention time with the corresponding standards (37-component FAME mix). The quantification was expressed as a percentage of total fatty acids.

2.7. Nutritional quality indices based on the healthy lipid profile

Nutritional quality indices were obtained from the fatty acid profile. Sanigenic indices were determined using equations provided in the scientific literature (Domínguez and Lorenzo, 2014; Wołoszyn *et al*., 2020; Ramos-Escudero *et al*., 2022; Frunză *et al*., 2023). These indices were: Desirable fatty acids (DFA), essential fatty acids (EFA), nutritive value index (NVI), health-promoting index (HPI), atherogenic index (AI), thrombogenic index (TI), and hypocholesterolemic and hypercholesterolemic ratio (h/H).

2.8. Microbial analysis

Microbial assays were carried out according to standardized methods. To determine the total viable mesophilic bacterial count, 10 g of ground sample were homogenized with 90 mL of peptone water. One mL of homogenate and its serial dilutions were transferred to Petri dishes containing plate count agar. The plates were incubated at 37 °C for 24 h, and then colony-forming unit (CFU) counts were taken according to the procedure described in ISO 4833-1:2013.

Mold and yeast counts were taken according to the methodology described in ISO 21527-2:2008. One mL of the dilutions was inoculated onto Petri dishes containing a selective cultivation of Sabouraud dextrose agar. The plates were incubated aerobically at 25 °C for 5 days.

The total coliform count was selected as an indicator of hygiene and contamination. The total coliform assay was conducted by inoculating 1 mL of each dilution with 15 mL of molten violet red bile agar (VRBGA). The plates were incubated at 37 °C for 24 h according to the methodology established by ISO 4832:2006.

The prevalence of *Salmonella* spp. was determined according to the method described in UNE-EN ISO 6579. For pre-enrichment, 25 g of ground sample were mixed with 250 mL of peptone water and then incubated at 37 °C for 16 h. Enrichment was then performed in selective medium, with 2 mL transferred to tubes containing Rappaport-Vassiliadis soya peptone broth and incubated at 41.5 °C for 22 h. Finally, the isolate was placed on Eosin Methylene Blue (EMB) agar, which was incubated at 37 °C for 24 h. The presence of colorless colonies characteristic of *Salmonella* ssp. was subsequently evaluated.

2.9. Statistical analysis

Results are presented as mean ± standard deviation. The Shapiro–Wilk test was used to verify whether the data are normally distributed and homoscedasticity assumptions exist as executed in the Develve v4.14.1.0, Statistical software. A one-way analysis of variance (ANOVA) was used to determine whether there was a significant difference between treatments (pasteurization, sterilization, and untreated); while Tukey's Honestly Significant Difference (HSD) post-hoc test (95% significance level) was applied to compare the means of the variables, including proximate composition, pH, TBARS, color parameters, and fatty acid profile. The ANOVA and Tukey HSD test were performed using Minitab v18, Statistical software.

3. RESULTS AND DISCUSSION

3.1. Proximate composition, pH and lipid oxidation

Table 1 shows the effect of heat treatment on the proximate composition, pH, and lipid oxidation of guinea pig meat. The protein content in the raw sample has a lower concentration (17.80 g/100 g), compared to the pasteurized (24.18 g/100 g) and sterilized (23.56 g/100 g) samples. After heat treatment, the pasteurized and sterilized samples increased by 6.38 and 5.76 g/100 g, respectively, compared to the raw sample. On the other hand, there was an increase in fat content in both heat treatments with values of 5.20 and 5.28 g/100 g, respectively, compared to the raw sample (4.65 g/100g). The fat content did not show significant differences between heat treatment by pasteurization and sterilization. Similar responses with significant increases were observed by Abdel-Naeem *et al*. (2021) for the protein, fat and volatile compound contents in rabbit meat subjected to different methods such as boiling and pan-frying. Furthermore, the fat content in guinea pig meat was higher than other meats such as rabbit (1.5 g/100 g), chicken (2.7 g/100 g), and beef (4.4 g/100 g). The effect of heat treatment and raw meat was not significant and differences were detected ($p > 0.05$) for the ash content, which ranged from 0.81 to 0.92 g/100 g. These values were slightly lower than those reported for guinea pig meat from three genetic lines (Criollo, Andino, and improved Peruvian), whose values ranged from 1.08 to 1.16 g/100 g (Flores-Mancheno *et al*., 2017). The moisture content was lower in the heat-treated samples compared to the raw sample. For example, the effect of heat treatment of rabbit meat with boiling and frying with different cooking processing times showed a significant decrease with respect to the control treatment (Zhang *et al*., 2014). Generally, the moisture contents of meats from various edible animals such as guinea pig, hare, rabbit, pork, beef, goat, and chicken ranges from 61.4 to 75.3 g/100 g (Flores-Mancheno *et al*., 2017; Frunză *et al*., 2023). The free nitrogen content is represented by sugars, starches, and other non-nitrogenous components in meat and meat derivatives. This fraction in guinea pig meat ranged from 0.58 to 1.73 g/100 g, while in hare and rabbit meat from different muscle parts such as the dorsal torso (longissimus dorsi), thigh (semimembranosus), and upper arm (triceps brachii), it ranged from 0.1 to 0.51 g/100 g (Frunză *et al*., 2023). Regarding the gross energy value, it ranged from 124.67 to 157.82 kcal/100g. These values are represented by their high protein content and low-fat content. Furthermore, guinea pig meat can be compared to rabbit and free-range meat, which ranged from 108 to 117 kcal/100 g (Frunză *et al*., 2023).

TABLE 1. Effect of thermal processing methods on proximate composition (g/100g), gross energy (kcal/100g), pH, and TBARS (mg MDA/kg) of guinea pig (*Cavia porcellus*) meat

Thermal processing	Moisture)	Protein	Fat	Ash	Nitrogen free extract	Gross energy	pH	TBARS
Raw	74.90±0.17^{a}	17.80±0.3b	4.65±0.16^{b}	0.92±0.07^{a}	1.73±0.04^{a}	124.67±0.18^{c}	6.43±0.03^{c}	1.17 ±0.07^{b}
Pasteurization	69.23±0.31^{c}	24.18±0.36^{a}	5.20±0.09^{a}	0.81±0.05^{a}	0.58±0.09^{c}	152.02±0.76^{b}	6.79±0.04^{a}	4.19±0.52^{a}
Sterilization	67.88±0.26^{b}	24.56±0.21^{a}	5.28±0.07^{a}	0.90±0.01^{a}	1.38±0.08^{b}	157.82±0.91^{a}	6.63±0.04^{b}	3.43±0.07^{a}
F-value	695.50	489.52	26.86	2.27	143.48	984.4	63.89	78.39
Pr>F	<0.001*	<0.001*	0.001*	0.18^{ns}	<0.001*	<0.001*	0.004*	<0.001*

Data expressed as mean ± SD (n=3). Values in the same column with different superscripts indicate differences ($p < 0.05$) according to Tukey's Honestly Significant Difference (HSD) test. ns Not significant. TBARS, thiobarbituric acid reactive substances. MDA, malondialdehyde.

On the other hand, the pH of both raw and thermally processed guinea pig meat showed slightly acidic values between 6.43 and 6.79. These values agree with those reported by Flores-Mancheno *et al*. (2017), who determined an average value of 6.42 in the guinea pig meat from three genetic lines. Changes in the pH value of meat may be associated with muscle metabolism, as it has a higher oxidative metabolism and lower glycolytic potential. For example, the pH of hare and rabbit meat after 24 to 48 h of slaughter ranged from 5.6 to 6.1 (Frunză *et al*., 2023), while chicken breast cooked by sous vide at different temperatures and times showed significant differences with respect to temperature with pH values fluctuating between 6.07 to 6.30 (Haghighi *et al*., 2021).

Regarding the thiobarbituric acid reactants, an increase in lipid oxidation was observed in the heat treatment processes (3.43 to 4.19 mg MDA/kg) compared to the control treatment (1.17 mg MDA/kg). Neither pasteurization (92 °C for 30 min) nor sterilization (121 °C for 20 min) showed significant differences. In spite of observing high values of malondialdehyde , they may be considered within the acceptable limit of between 2 and 4 mg MDA/kg. Ntzimani *et al*. (2025) reported that these values can be observed in processed and cooked meats due to an increase in added fats and high amounts of polyunsaturated fatty acids. Generally, temperature increases the formation of the TBARS value. In this regard, Xiong *et al*. (2020) reported an increase in malondialdehyde production at temperatures above 70 °C in chicken meat, when the temperature was 100 °C for 10 min of heating the MDA values were approximately 0.8 to 1.2 mg/kg. On the other hand, Haghighi *et al*. (2021) reported that cooking chicken breast fillets using sous vide at 80 °C with heating times of 60 and 150 min showed an increase in TBARS values from 2.31 to 2.60 mg MDA/kg, respectively. Several compounds (polyunsaturated fatty acids, iron, myoglobin, and hydrogen peroxide) can promote increased lipid oxidation in meat as temperatures and heating times increase.

3.2. Color measurements

The color parameters of the guinea pig meat and skin are summarized in Table 2. The L^*, a^*, b^*, C^* y $H°$ values show the effects of heat treatment on the hindquarter and forequarter compared to the raw sample. Regarding the L^* parameter, an increase in lightness was observed due to pasteurization (55.83 units) and sterilization (42.97 units), while the raw sample was 31 units. These results showed similar trends in grass carp meat where heat treatment by steaming, boiling, frying, roasting and sous vide showed L^* values between ~28 to ~60 units, while the untreated sample presented a lower value of ~17 units (Tan *et al*., 2024). On the other hand, the color parameters b^* and $H°$ showed significant increases for the heat treatments that varied between 18.08 to 21.06 units and 63.28 to 56.10 units, respectively, while the b^* value for the raw sample was 12.48 units and the value of $H°$ was 35.39 units. Kaliniak-Dziura *et al*. (2022) reported increases in yellowness and hue angle in the longissimus thoracis muscle in unweaned Limousin calves, while redness ($+a^*$) decreased and saturation color (C^*) showed slight variations depending on cooking methods such as grilling, sous vide, and steaming. These last parameters, both the value of a^* (9.97 to 14.27 units) and C^* (20.72 to 25.50 units) in guinea pig meat showed similar trends for pasteurization and sterilization treatments. Changes in the chromatic parameters in guinea pig meat may be mainly due to the degradation of myoglobin, which generates an increase in the L^* parameter and a decrease in the a^* chromatic parameter. On the other hand, the increase in the b^* value is due to non-enzymatic browning reactions (Kaliniak-Dziura *et al*., 2022; Tan *et al*., 2024).

Regarding skin color measurements, chromatic parameters a^* (8.71 to 11.62 units), b^* (24.80 to 26.70 units), and C^* (26.32 to 29.18 units) increased significantly ($p < 0.05$) compared to the raw sample ($a^* = 5.85$; $b^* = 17.77$; $C^* = 18.76$). On the other hand, the lightness of the raw sample was 71.41 units, while the effects of heat treatment produced a decrease during pasteurization ($L^* = 55.22$ units) and sterilization ($L^* = 50.83$ units). Regarding the H° value, no significant differences were detected ($p > 0.05$). Changes in chromatic parameters are due to the denaturation of proteins that cause darkening of the skin surface after heat treatment, as occurs with jumbo squid (*Dosidicus gigas*) (Vega-Gálvez *et al*., 2011).

TABLE 2. Effect of thermal processing methods on color parameters (values in *L, *a** and *b**) of guinea pig (*Cavia porcellus*) meat**

Sample/Parameters	Thermal processing			F-value	Pr>F
	Raw	Pasteurization	Sterilization		
Hindquarter and forequarter					
Color *L**	31.00±9.31^{c}	55.83±4.72^{a}	42.97±4.51^{b}	35.67	<0.001*
Color *a**	23.79±5.01^{c}	9.97±1.96^{a}	14.27±2.40^{b}	43.41	<0.001*
Color *b**	12.48±3.34^{b}	18.08±1.88^{a}	21.06±2.67^{a}	26.12	<0.001*
Chroma	26.94±5.63^{a}	20.72±1.94^{b}	25.50±3.01^{a}	7.53	0.003*
Hue angle	35.39±7.09^{b}	63.28±2.74^{a}	56.10±1.53^{a}	31.36	<0.001*
Skin					
Color *L**	71.41±4.09^{a}	55.22±4.35b	50.83±4.13^{b}	67.03	<0.001*
Color *a**	5.85±1.46^{c}	11.62±1.94^{a}	8.71±2.01^{b}	25.06	<0.001*
Color *b**	17.77±1.64^{b}	26.70±2.53^{a}	24.80±1.73^{a}	54.83	<0.001*
Chroma	18.76±1.68^{c}	29.18±2.25^{a}	26.32±2.23^{b}	60.77	<0.001*
Hue angle	72.21±2.67^{a}	67.27±1.92^{a}	70.82±3.84^{a}	2.29	0.18^{ns}

Data expressed as mean ± SD (n=5). Values in the same row with different superscripts indicate differences ($p < 0.05$) according to Tukey's Honestly Significant Difference (HSD) test. ns Not significant. TBARS, thiobarbituric acid reactive substances.

3.3. Fatty acid composition and health lipid indices

The fatty acid profiles of guinea pig meat subjected to pasteurization and sterilization heat treatment are presented in Table 3. Several fatty acids did not show significant differences, with p values greater than 0.05. These fatty acids were pentadecaenoic, palmitic, heptadecaenoic, stearic, behenic, eicosenoic, eicosadienoic, clupanodonic, and docosahexaenoic. On the other hand, the significant fatty acids ($p < 0.05$) were oleic, arachidic, vaccenic, linoleic, α-linolenic, and palmitoleic. A slight increase in MUFAs was found in guinea pig meat treated with sterilization, while a significant increase in PUFAs was observed in the pasteurized meat. However, the fatty acid profile in guinea pig meat is strongly associated with the genotype and the type of food consumed. In this regard, Hidalgo-Lozano and Vílchez-Perales (2023) reported the fatty acid profiles of two guinea pig genotypes, namely Peru and Cieneguilla, which showed higher oleic acid values between 31.61 and 32.07%, respectively, compared to the present study, which presented oleic acid values in raw, pasteurized and sterilized samples of 19.95, 19.07 and 19.48, respectively. Other polyunsaturated fatty acids, such as linoleic acid (34.28 to 35.49%) and α-linolenic acid (4.93 to 5.59%), were higher than those reported by Hidalgo-Lozano and Vílchez-Perales (2023). Regarding heat treatment, Tan *et al*. (2024) reported that the fatty acid profile of grass carp meat in C16:0, C16:1(n-9), C18:1(n-9), C18:2(n-6), C18:3(n-3), and C20:4(n-6) varied according to the heating method. The raw sample showed very similar results to the steaming, boiling, and sous vide methods, although the fatty acid profiles decreased with frying and roasting. The SFA of guinea pig meat ranged from 35.03 to 35.51%, while the MUFA varied between 21.37 to 22.25% and the PUFA presented values between 42.42 to 43.33%. These values are very comparable with hare meat (SFA = 34.47%; MUFA = 20.77%; PUFA = 42.37%) and rabbit meat (SFA = 37.42%; MUFA = 30.93%; PUFA = 28.41%) (Króliczewska *et al*., 2018), while in the Celta pig breed (*Longissimus dorsi*, dorsal fat and ventral fat) the total SFA content ranged from 38.30 to 43.44%, MUFA between 44.21 and 52.70% and PUFA fluctuated between 7.55 and 14.03% (Domínguez and Lorenzo, 2014). Other types of meat from various animal species such as lamb (SFA = 51.99%; MUFA = 23.55%; PUFA = 6.75%), beef (SFA = 58.13%; MUFA = 30.55%; PUFA = 7.25%), and turkey (SFA = 40.40%; MUFA = 28.63%; PUFA = 12.25%) (Lisitsyn *et al*., 2017) compared to guinea pig meat were higher in saturated fatty acids and much lower in polyunsaturated fatty acids.

Table 4 shows the lipid health indices of raw guinea pig meat and those heat-treated with pasteurization and sterilization. The effect of heat treatment showed no difference between the raw and cooked samples with respect to nutritional quality indices.

Essential fatty acids (EFAs) are important compounds for the human body, although these fatty acids cannot be synthesized in the body, so they must be obtained through the diet. On the other hand, desirable fatty acids (DFA) have been reported for their important role in biological processes such as long-chain

omega-3 fatty acids and MUFAs, which are considered beneficial for human health. In this study, the guinea pig meat had DFA and EFA values of 73.52 and 40.25%, respectively. The DFA values of guinea pig meat were very similar to hare, rabbit and goose meat (Wereńska *et al*., 2021; Frunză *et al*., 2023), although with respect to essential fatty acids guinea pig meat was very similar to hare meat but much higher than rabbit meat. The NVI and HPI values are related to the quality of nutrients that have an impact on health. Guinea pig meat has an NVI (1.24) and is lower than hare, rabbit, and goose meat and higher than Pekin duck meat (Wasilewski *et al*., 2023), while the HPI value was higher than Pekin duck meat. High values have a positive association with reducing heart disease and improving cardiovascular health (Lloyd-Jones *et al*., 2010). The AI and TI of guinea pig meat were 0.57 and 0.64, respectively. Although these indicators are used to assess the health risks of consumers, especially in the development of cardiovascular diseases (saturated fatty acids), they are also used to prevent these risks (polyunsaturated fatty acids). In this regard, Wereńska *et al*. (2021) commented that lower AI and TI values provide a greater protective effect against coronary heart disease. They also indicated that values lower than 1 and 0.5, respectively, are desirable and recommended for human health. In this study, guinea pig meat was lower for AI and slightly higher for TI. The hypocholesterolemic and hypercholesterolemic ratio (h/H) was 2.56. From a nutritional point of view, the higher the h/H ratio value, the better the benefit of the food in the diet, since the food will provide a greater amount of unsaturated fatty acids in relation to proatherogenic fatty acids (Wołoszyn *et al*., 2020).

TABLE 3. Effect of thermal processing methods on fatty acid profile (%) of guinea pig (*Cavia porcellus*) meat

Fatty acids	Shorthand abbreviation	Thermal processing			F-value	Pr>F
		Raw	Pasteurization	Sterilization		
Myristic	C14:0	1.25±0.01^{b}	1.27±0.01^{b}	1.35±0.03^{a}	16.62	0.02*
Pentadecaenoic	C15:0	0.40±0.01^{a}	0.40±0.01^{a}	0.40±0.00^{a}	0.2	0.82^{ns}
Palmitic	C16:0	22.75±0.09^{a}	22.98±0.23^{a}	22.93±0.01^{a}	1.54	0.34^{ns}
Heptadecaenoic	C17:0	0.68±0.03^{a}	0.68±0.02^{a}	0.69±0.01^{a}	0.12	0.89^{ns}
Stearic	C18:0	8.59±0.05^{a}	8.69±0.04^{a}	9.08±0.52^{a}	1.48	0.35^{ns}
Arachidic	C20:0	0.19±0.01^{a}	0.17±0.01^{ab}	0.16±0.00^{b}	10.5	0.04*
Behenic	C22:0	1.19±0.16^{a}	1.13±0.03^{a}	0.91±0.01^{a}	5.41	0.10^{ns}
Palmitoleic	C16:1(n-9)	0.81±0.01^{b}	0.83±0.007^{b}	1.04±0.01^{a}	220.78	<0.001*
Oleic acid	C18:1(n-9)	19.95±0.03^{a}	19.07±0.071^{b}	19.48±0.23^{ab}	20.41	0.02*
Eicosenoic	C20:1(n-9)	0.33±0.01^{a}	0.30±0.014^{a}	0.31±0.01^{a}	3.5	0.16^{ns}
Vaccenic acid	C18:1(n-7)	1.16±0.00^{b}	1.17±0.014^{b}	1.25±0.01^{a}	36.5	0.008*
Linoleic	C18:2(n-6)	35.49±0.05^{a}	35.30±0.01^{a}	34.28±0.25^{b}	31.71	0.007*
α-Linolenic	C18:3(n-3)	4.93±0.04^{c}	5.59±0.021^{a}	5.17±0.01^{b}	351.5	<0.001*
Eicosadienoic	C20:2(n-6)	0.45±0.02^{a}	0.49±0.01^{a}	0.46±0.00^{a}	4.9	0.11^{ns}
Eicosatrienoic	C20:3(n-3)	1.47±0.01^{b}	1.46±0.01^{b}	1.91±0.03^{a}	50.17	<0.001*
Clupanodonic	C22:5(n-3)	0.27±0.14^{a}	0.38±0.01^{a}	0.46±0.01^{a}	2.68	0.21^{ns}
Docosahexaenoic	C22:6(n-3)	0.14±0.01^{a}	0.13±0.00^{a}	0.15±0.01^{a}	3.5	0.16^{ns}
Saturated fatty acids, SFA (%)		35.03±0.04^{b}	35.31±0.19^{a}	35.51±0.53^{a}	1.06	0.44^{ns}
Monounsaturated fatty acids, MUFA (%)		22.25±0.02^{a}	21.37±0.06^{b}	22.08±0.22^{a}	24.88	0.01*
Polyunsaturated fatty acids, PUFA (%)		42.74±0.02^{ab}	43.33±0.13^{a}	42.42±0.31^{b}	11.35	0.04*

Data expressed as mean ± SD (n=2). Values in the same row with different superscripts indicate differences ($p < 0.05$) according to Tukey's Honestly Significant Difference (HSD) test. ns Not significant.

TABLE 4. Healthy lipid indices for of guinea pig (*Cavia porcellus*) meat

Healthy lipid indices	Thermal processing				Hare[1]	Rabbit[1]	Goose[2]	Duck[3]
	Raw	Pasteurization	Sterilization	Average±SD				
Desirable fatty acids (DFA)	73.58	73.39	73.58	73.52±0.11	78.22	69.50	75.97	
Essential fatty acids (EFA)	40.42	40.89	39.45	40.25±0.73	43.42	25.37		
Nutritive value index (NVI)	1.25	1.21	1.25	1.24±0.02	1.48	1.34	2.48	0.7
Health-promoting index (HPI)	2.34	2.31	2.28	2.31±0.02				0.9
Atherogenic index (AI)	0.56	0.57	0.58	0.57±0.01	0.78	0.73	0.31	1.1
Thrombogenic index (TI)	0.66	0.64	0.65	0.64±0.004	0.66	0.39	0.74	2.7
hypocholesterolemic and hypercholesterolemic ratio (h/H)	2.61	2.57	2.55	2.56±0.02	3.58	1.98	3.49	0.9

[1]Hare and rabbit meat from different muscle regions (dorsal torso-*Longissimus dorsi*, thigh-Semimembranosus, and upper arm-Triceps brachii) (Frunză *et al*., 2023). [2]Goose meat cooked with different types of heat treatment (water bath cooking, grilling, oven convection roasting, and pan frying) (Wereńska *et al*., 2021). [3]Leg muscle lipids of Pekin ducks (Wasilewski *et al*., 2023).

3.4. Microbiological characteristics

The microorganism counts of the raw sample and the samples treated with pasteurization and sterilization are shown in Table 5. Microbial assays such as total plate count, total coliform, yeasts and molds and *Salmonella* spp were selected as indicators of deterioration and contamination of guinea pig meat. These tests are common for the evaluation of the microbiological quality of meat (Atlabachew and Mamo, 2021), and high counts of these microorganisms express poor hygienic handling practices. The raw guinea pig meat sample showed 5.15 $\log_{10}$ cfu/g and 4.59 $\log_{10}$ cfu/g total aerobic plate count and total coliform, respectively. The yeast and mold count showed 2.20 $\log_{10}$ cfu/g. On the other hand, pasteurized and sterilized samples showed counts less than 1.0 $\log_{10}$ cfu/g. In all samples, the presence of *Salmonella* spp. was not detected in 25 g of sample. Previous reports on guinea pig meat from three genetic lines showed total coliform counts of 1.0 $\log_{10}$ cfu/g, *Escherichia coli* of 1.0 $\log_{10}$ cfu/g, *Staphylococcus aureus* of 2.5 $\log_{10}$ cfu/g, while *Salmonella* spp. was absent (Flores-Mancheno *et al*., 2017). Another report mentioned that guinea pig meat preserved with vacuum-packed oregano essential oil and stored at –10 °C for 0 to 70 days showed psychrophilic bacteria counts ranging from ~1.83 $\log_{10}$ cfu/g to ~3.20 $\log_{10}$ cfu/g (Moreno and Arteaga-Miñano, 2018). Heat treatment methods have a significant effect on reducing microbial load. For example, in chicken fillets cooked sous vide at different temperatures and times, the presence of total mesophilic aerobic bacteria, *Enterobacteriaceae*, and *Psychrotrophic* aerobic bacteria was not detected (Haghighi *et al*., 2021). These results are consistent with the microbiological criteria for cooked meats, which focus on the absence of specific pathogens. Coliform counts and total plate counts (≤ 10 cfu/g) are considered indicative of high levels of hygiene and safe for consumption.

TABLE 5. Changes in the microbiological quality of guinea pig (*Cavia porcellus*) meat with various thermal processing methods

Microorganism type	Thermal processing		
	Raw	Pasteurization	Sterilization
Total aerobic plate count, $\log_{10}$ cfu/g	5.15±0.02	<10	<10
Total coliform bacteria, $\log_{10}$ cfu/g	4.59±0.34	<10	<10
Yeasts and moulds, $\log_{10}$ cfu/g	2.20±0.04	<10	<10
Salmonella spp. (absent in 25 g)	N.D	N.D	N.D

Values expressed as mean ± SD of duplicate determinations. cfu, colony-forming unit. N.D, Not determined.

4. CONCLUSIONS

Commercially, guinea pig meat is sold fresh in vacuum packaging; however, its shelf life is short, resulting in losses for producers. The effects of pasteurization and sterilization on the color, chemical composition, lipid oxidation, and microbiological characteristics of guinea pig (*Cavia porcellus*) meat were studied. Heat treatment with pasteurization or sterilization effectively extended the shelf life of guinea pig meat without

significantly affecting its nutritional composition or lipid profile. The application of heat treatments contributes as an alternative to preserving guinea pig meat without drastically altering its nutritional properties.

RESEARCH DATA POLICY DATA AVAILABILITY

Data from this manuscript will be available from the corresponding author upon reasonable request.

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DECLARATION OF COMPETING INTEREST

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R. Alzamora-Herrera: Investigation, Formal analysis, Data analysis, and Manuscript writing.
M. Ramos-Escudero: Formal analysis, Investigation, and Methodology.
E. Barnett Mendoza: Resources, Supervision, Writing – review and editing.
F. Ramos-Escudero: Conceptualization, Supervision, Manuscript editing and review.

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